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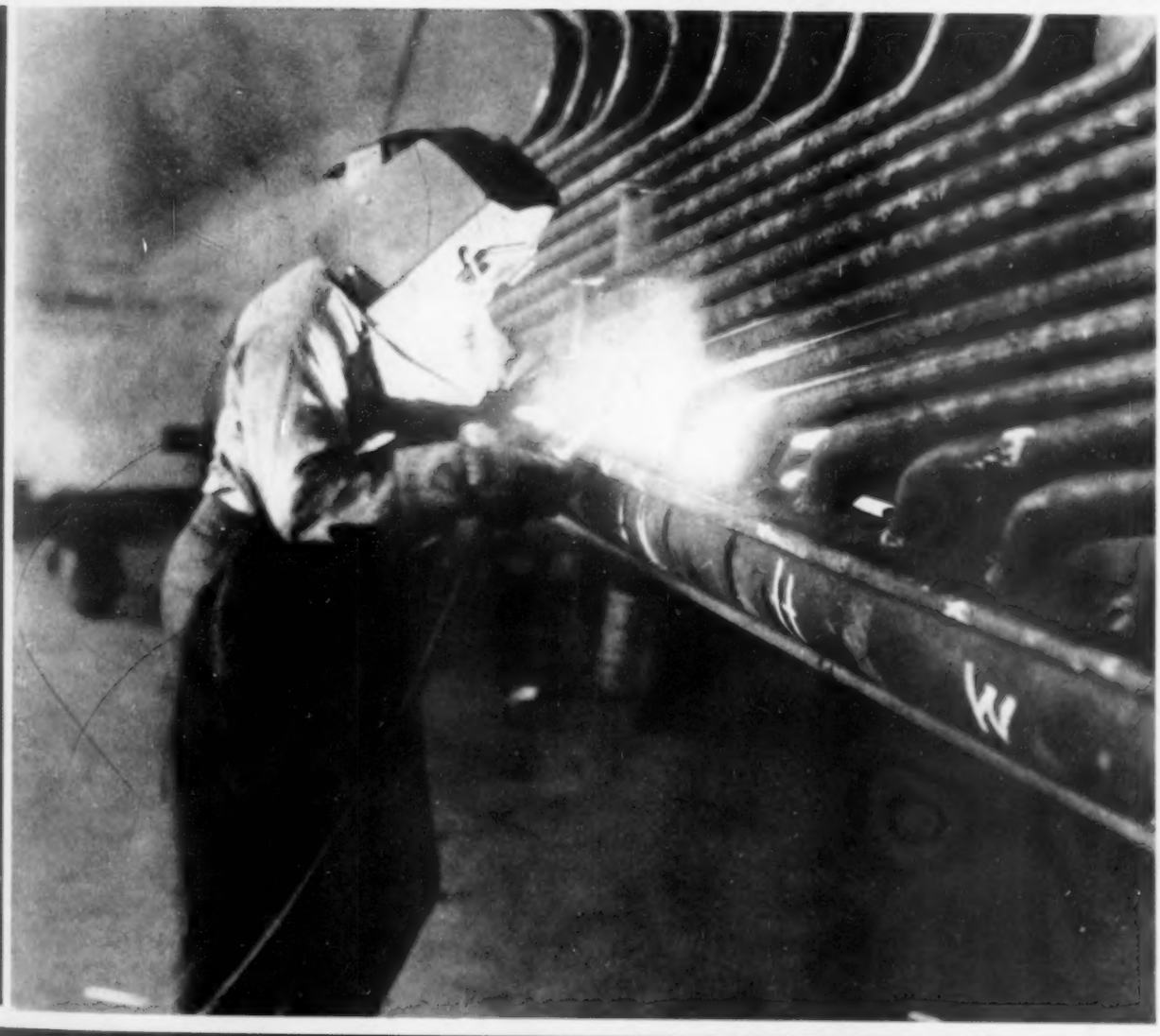

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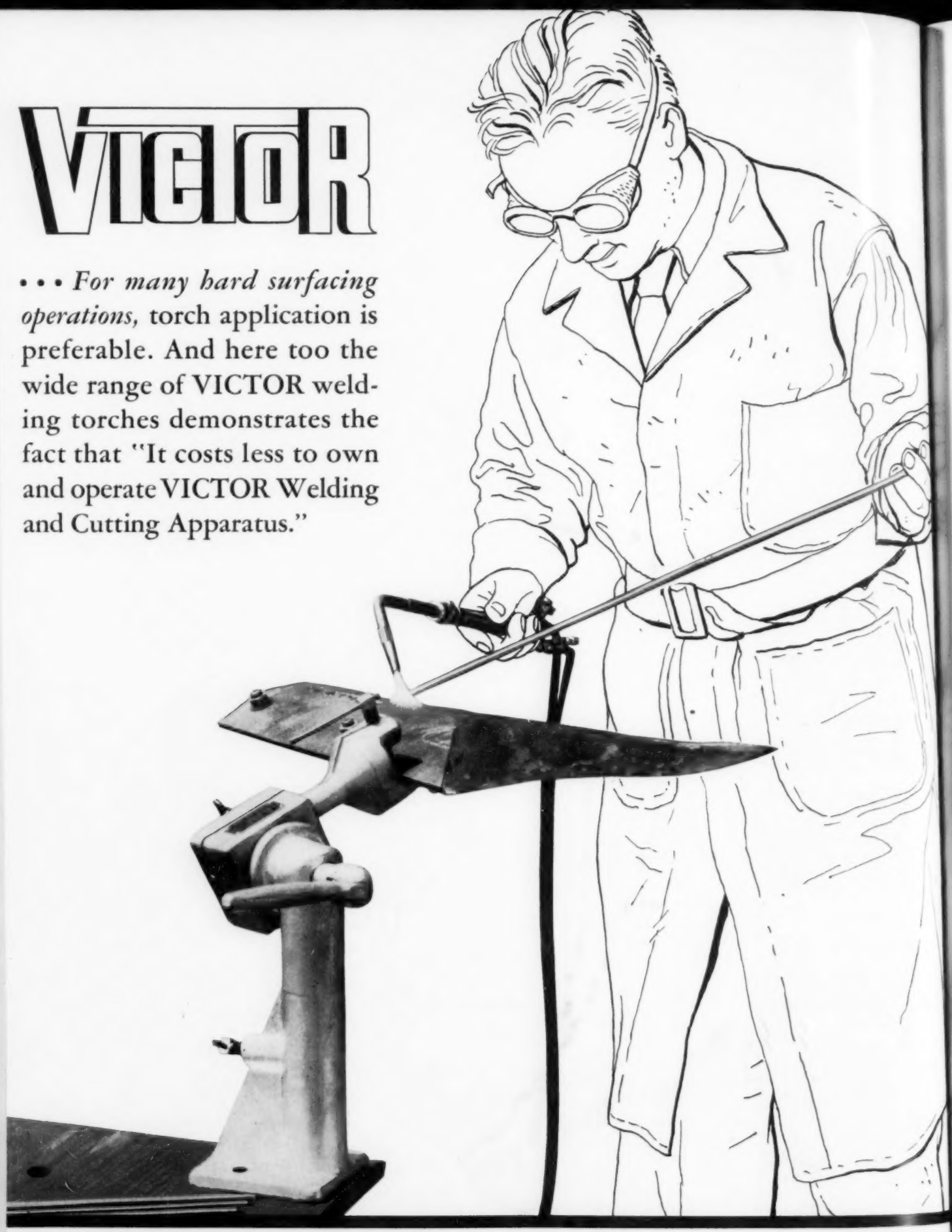

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SEPTEMBER, 1941

Welded Pipe Headers and Their Reinforcement*

By Eric R. Seabloom†

WELDED piping has been in general use in cross country gas and oil transmission systems, oil refineries, power plants and various process industries for many years. In most of this piping, circumferential line joints predominate, the design and welding of which have been quite well established by numerous investigations and extensive experience, plus the formulation of definite code rules. The qualification of welding procedures and operators as required by codes and many specifications has added to their reliability by controlled workmanship. The problems of stresses associated with circumferential butt and fillet line welds are not of any great consequence, especially with the plain carbon steels. Furthermore, no reduction in strength results because the tubular cross sections are retained. Hence, the stresses due to internal pressure remain unchanged.

In many welded piping installations, fabricated branch connections, headers and manifolds are also employed, but these are subject to higher stresses than line joints, especially if they are constructed from pipe of the same wall thickness as the straight lengths. One of the major reasons for this is that there is a deviation from the strong circular cross section when a branch outlet is attached. This is particularly true of nozzles of the same size as the header, and also with nozzles approaching the size of the header. The connections formed are tee shaped, and the flat sides deform more readily under internal pressure than circular sections, due to increased pressure areas. This deformation or yielding is such that the flat sides of the connection tend to form a spherical shape; thus some redistribution of stresses occurs, but extremely high stresses are also built up at various locations, notably at the outer surfaces of the flat sides and at the inner surfaces near the crotches. The result is that the pressure to cause yielding, as well as the ultimate strength of the branch assembly or manifold, is considerably lower than with straight lengths of pipe without any openings.

Effect of Nozzles on Strength of Piping

To illustrate this, some data are presented from a series of tests we conducted a few years ago to determine the reduction in strength caused by the attachment of nozzles to piping. The tests were made with 8-in. Schedule 40 A. S. T. M. Designation A 106 Grade A carbon steel seamless tubing on sections 5 feet long, cut from one length of pipe to avoid discrepancies in results due to variations in physical properties of material. The ellipsoidal head end closures and the nozzles were arc welded, using shielded mild carbon steel electrodes. The pipe without any nozzle, as shown in Fig. 1, ruptured at 4600-lb. hydrostatic pressure, while the manifold illustrated in Fig. 2, having an 8-in. unreinforced nozzle at the center, failed near the crotch at 3200-lb. pressure or 30% lower than the straight length of pipe. A manifold with a 4-in. unreinforced nozzle failed in the crotch at 4650-lb. pressure, as shown in Fig. 3, or practically at the same pressure as the straight length. During these pressure tests, deflection readings were taken by means of dial indicators at various locations on the specimens. The diametrical deformations obtained at the center sections of each are plotted in Fig. 4. It will be observed that the proportional limit of the full size unreinforced branch connection is about 60% lower than that obtained on the straight length of pipe. Therefore, it can be seen that nozzle attachments, especially those of full size, should be reinforced, particularly when piping is to operate at its maximum rated pressure and temperature.

Up to the present time the A. S. A. Code for Pressure Piping has not published any definite rules for the reinforcement of welded headers or branch connections, and, in the absence of regulations, engineers have applied various means of reinforcement. Some of these were not entirely satisfactory, and others, proved by tests and service, pointed the way to formulation of design rules, which will be incorporated in the latest edition of the A. S. A. Code for Pressure Piping.

Early attempts at nozzle reinforcements used gusset plates, attached by welding at the crotches of the manifold connections, in combination with horse-shoe reinforcing ribs, which encircled the round bottom portions and extended up onto the nozzles. It has been found,

Fig. 1—Failure of 8-In. Pipe Without Openings

Fig. 2—Failure of 8-In. Header with 8-In. Unreinforced Nozzle

* Presented before the Natural Gas Convention of the American Gas Association, Dallas, Texas, May 7, 1941.
† Supervising Engineer Crane Co., Research Laboratories, Chicago, Ill.

Fig. 3—Failure of 8-In. Header with 4-In. Unreinforced Nozzle

by both tests and experience, that such reinforcements are undesirable as stress distribution is not obtained, resulting rather in stress concentrations of high magnitude.

Some years ago we had occasion to test a 24-in. pipe header having one 24-in. and two 18-in. branch connections. The pipe wall thickness of the header was $^1/_2$ in. and the actual tensile strength of the material averaged 74,860 lb. per sq. in., with a yield point of 45,780 lb. per sq. in. Reinforcement was by means of horse-shoe rib and gusset plates, as previously described, on the 24-in. nozzle and merely by gusset plates on the 18-in. connections. Figure 5 shows the header set up for hydrostatic test with deflectometers, dial indicators and strain gages mounted at various critical sections to ascertain the deflections and stresses caused by internal pressure. This header was intended to operate at a maximum working pressure of 800 lb. per sq. in. and to pass a 1200-lb. hydrostatic test. Several manifolds of this type failed in the crotches of the 24-in. nozzle connections at the test pressure while undergoing final hydrostatic inspections in various fabricating plants. It will be seen from Fig. 6 that excessive deformation occurred at the 18-in. and 24-in. nozzles, the proportional limit being reached at these points slightly above 800-lb. pressure. The stresses in some localized areas even exceeded the yield point of the material at the working pressure, as indicated by the strain gage readings recorded in Table 1. In comparing the actual bursting pressure of 1200 lb. obtained on some of these headers with the theoretical bursting pressure of 3118 lb. per sq. in. as calculated by Barlow's formula for pipe of the same diameter, wall thickness and tensile

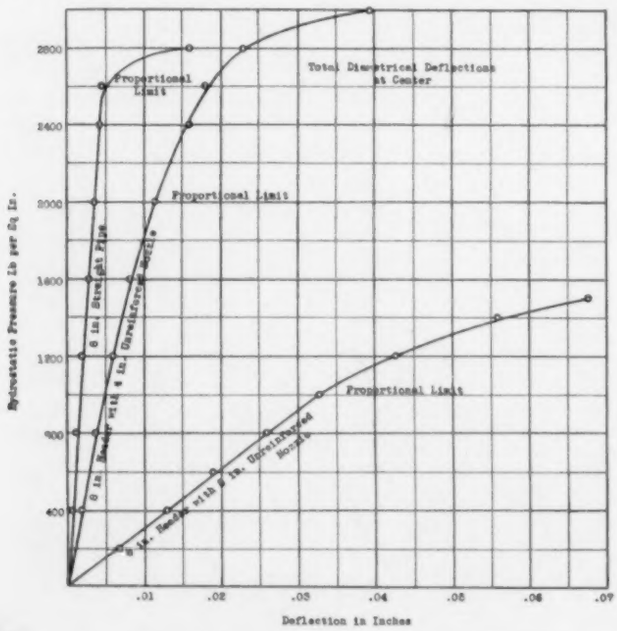


Fig. 4—Diametrical Deflections of Pipe and Headers Under Internal Pressure

Table 1—Stresses in Various Sections of 24-In. Header at 800 Pounds Internal Pressure

Location	Deformation per In.	Stress in Lb. per Sq. In.
Gusset plates at 24-in. nozzle		
Right	0.00036	10440
Left	0.00044	12760
Gusset plates at 18-in. nozzle		
Right	0.00015	4350
Left	0.00036	10440
Circumferential on header		
Opposite 24-in. nozzle	0.00063	18270
	0.00052	15080
	0.00045	13050
Opposite 18-in. nozzle	0.00075	21750
	0.00120	34800
Circumferential on nozzles		
24-in. nozzle	0.00065	18850
18-in. nozzle	0.00055	15950
Parallel to 24-in. nozzle weld		
On header	0.00070	20300
On nozzle	0.00170	49300*
Parallel to 18-in. nozzle weld		
On header	0.00052	15080
On nozzle	0.00055	15950

NOTE: The stresses were calculated assuming a modulus of elasticity of 29,000,000 lb. per sq. in.

* This stress is beyond yield point of material, consequently is somewhat in error.

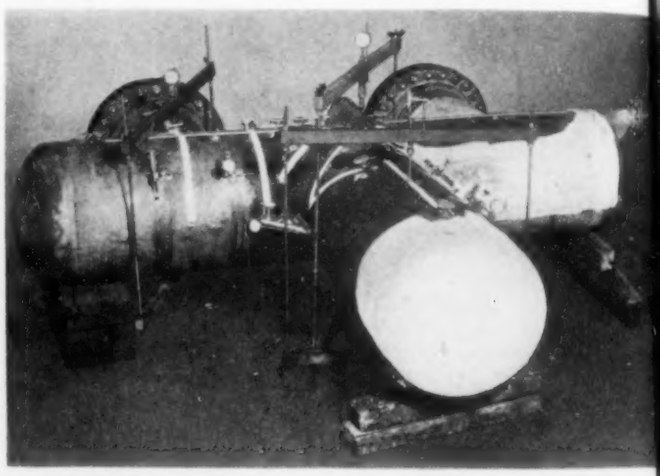


Fig. 5—A 24 x 24 x 18-In. Header with Gusset Plate and U-Shaped Rib Reinforcements Set Up for Hydrostatic Test

properties, but without any openings, a 60% reduction in strength is observed, which is considerably lower than noted on headers of smaller sizes. Consequently, it appears that such reinforcements are of little value.

Headers of this type of construction have shown signs of distress at the gusset plate welds when subjected to pulsating loads in service and also on extremely high temperature, as evidenced by investigations that we conducted on a 10-in., 1500-lb. fabricated steel tee of similar design, wherein the gusset plate and reinforcing rib welds failed after several thousand hours of testing at 1500-lb. pressure, with temperatures ranging from 900 to 1100° F. The tee is shown in Fig. 7, and the failure of a gusset plate weld is illustrated in Fig. 8.

As greater knowledge of stresses that occur in welded manifolds accumulated, pipe line constructors and manufacturers of welding fittings cooperated in designing improved nozzle reinforcements. One design used quite extensively in pipe line work is the saddle type, wherein a steel ring having an integral collar is fillet welded to the header and nozzle, as shown in Fig. 9.

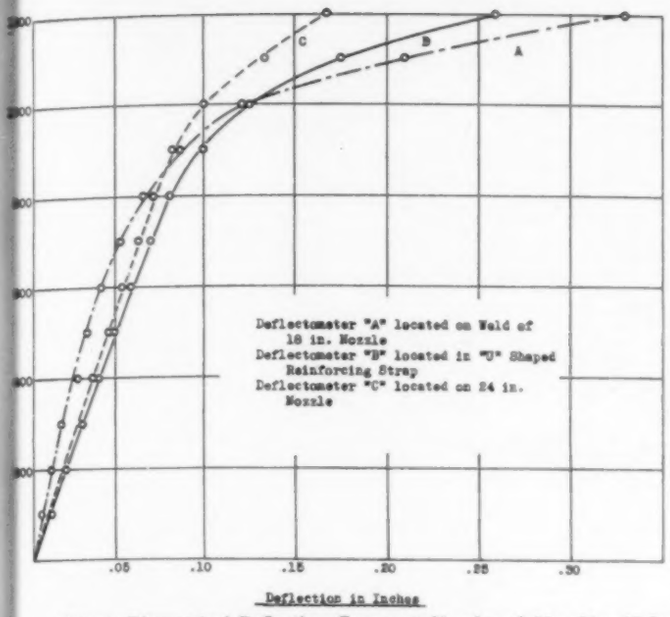


Fig. 6—Diametrical Deflection Curves at Nozzles of 24 x 24 x 18-In. Header

Reinforcements of this design reduce the deformation at the flat sides of the connection and, from all the evidence that has been gathered, provides adequate reinforcement under most conditions. Another style of reinforcement being used to a great extent is the ring type and it, no doubt, owes its popularity to the fact that it can be made without any die equipment, which, of course, is necessary on the saddle reinforcements. The rings are cut to proper shape by an oxyacetylene torch from either boiler plate or pipe and joined to the nozzle connections by fillet welds, as illustrated in Fig. 10. The thickness and width of the rings can be designed to meet most pressure and temperature service requirements.

Cooperative Tests

The ring type reinforcements employed on piping have generally been based on the rules prescribed in the A. S. M. E. Unfired Pressure Vessel Code or the A. S. M. E.-A. P. I. Code for Unfired Pressure Vessels for Petroleum Liquids and Gases. While these rules were primarily intended to apply to nozzles which do not exceed 60% of the shell diameter, designers have extended their use to piping, wherein the nozzles approach or even equal the diameter of the pipe header. Although the indications were that pipe header reinforcements based on this practice met service requirements satisfactorily, there remained some doubt in many designers' minds as to their adequacy, especially since the A. S. A. Code for Pressure Piping did not provide any rules for nozzle reinforcements. This resulted in the organization of a special Sub-Committee on Welded Branch Connections, of the A. S. A. Sectional Committee B-31. It became evident to this committee that a series of tests would be necessary in order to gather sufficient data to formulate design rules. Since this committee had no funds to conduct such an investigation, it appealed to the Pipe Fabrication Institute and other interested parties for their cooperation. Through the effort of the Institute, the National Valve & Mfg. Co. and the Grinnell Co. fabricated test headers from pipe donated by the National Tube Co. The Detroit Edison Co. also submitted a header for test, and Crane Co. constructed several manifolds to study various types of welding grooves on branch connections. All of the tests were conducted by the Crane Co. Research Laboratories.

The header fabricated by The Detroit Edison Co. was made from 8-in. Schedule 80 medium carbon seamless steel pipe of a special silicon-killed analysis, having a full-size branch connection of the same material. This manifold was first tested at the University of Michigan, both with and without a ring type reinforcement. The findings were reported in a paper presented by Dr. F. L. Everett

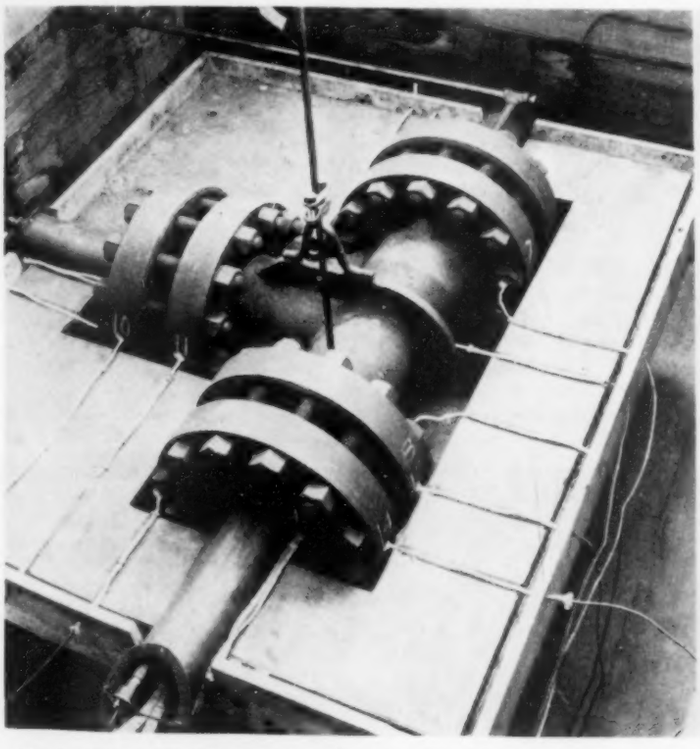


Fig. 7—Fabricated 1500-Pound Tee Having Gusset and U-Shaped Rib Reinforcements Set Up for Test at High Temperatures

Fig. 8—Failure of Gusset Plate Weld After Test on High Pressure and Temperatures

Table 2—Pipe Data, Theoretical and Actual Bursting Pressures

Type of header	8 x 8-In. reinforced	12 x 12-In. reinforced	12 x 6-In. unreinforced
Made by	Detroit Edison	National Valve	Grinell
Diameter and length of header	8.63 x 78 In.	12.75 x 120 In.	12.75 x 78 In.
Header wall thickness	0.50 In.	0.687 In.	0.687 In.
Diameter and length of nozzle	8.63 x 38 In.	12.75 x 60 In.	6.63 x 38 In.
Nozzle wall thickness	0.50 In.	0.687 In.	0.432 In.
A. S. T. M. pipe spec.	Special	A 106 (Grade B)	A 106 (Grade A)
Carbon content		0.27%	0.18%
Tensile strength	76125 lb. per sq. in.	79500 lb. per sq. in.	59375 lb. per sq. in.
Yield point	63975 lb. per sq. in.	69000 lb.	39925 lb.
Theoretical bursting pressure*	8820 lb.	8590 lb.	6400 lb.
Actual bursting pressure	8750 lb.	8000 lb.	5850 lb.
Difference	70 lb.	590 lb.	550 lb.
Percentage difference	0.8%	6.9%	8.6%

* Theoretical bursting pressures were based on Barlow's formula, i.e.,

$$\text{Bursting pressure in lb. per sq. in.} = \frac{2T \times TS}{\text{O.D.}}$$

where T = pipe wall thickness,
$T.S.$ = tensile strength in lb. per sq. in.
O.D. = outside diameter of pipe.

The calculations were based on the tensile values obtained from test bars cut from the headers after the destruction tests.

and Mr. Arthur McCutchan at the 1937 Annual Meeting of the A. S. M. E. and published in the July 1938 issue of the *A. S. M. E. Transactions*. After the completion of the tests at the university, the header incorporating the ring reinforcement was submitted to Crane Co. for further study and test to destruction in connection with the cooperative testing program described. As the header had been thoroughly explored by means of strain gages, there was no need for an additional investigation of this character. Consequently, it was decided to measure deformations of the manifold by means of dial indicators, as this would supplement the strain gage readings and would possibly bring about a better understanding of what occurs in the highly stressed areas. Figure 11 shows the header set up for hydrostatic test with 42 dial indicators, graduated in thousandths of an inch, located at the most critical sections.

A 12 x 12-in. header fabricated by the National Valve & Mfg. Co. was similar to the Detroit Edison manifold,

Fig. 9—Saddle Type Nozzle Reinforcement

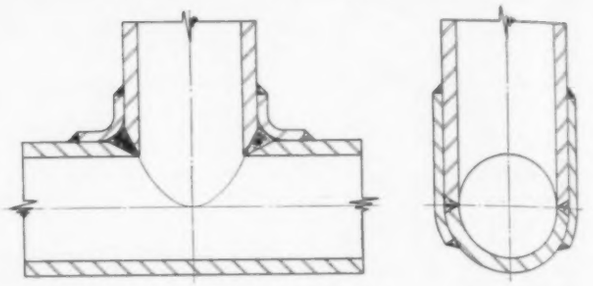
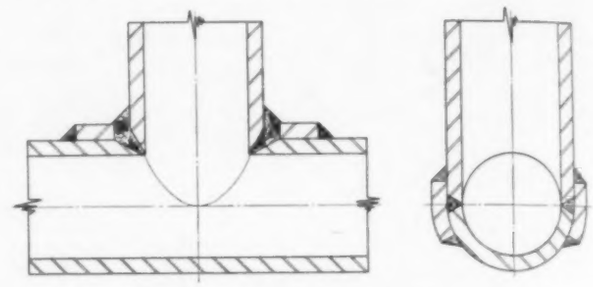


Fig. 10—Ring Type Nozzle Reinforcement



including the ring type reinforcement. It was also set up for test in a similar manner to the 8 x 8 in. header, as shown in Fig. 12. The locations of the dials on these two manifolds were substantially the same because the reinforcing rings were designed on the same basis, namely, modified A. S. M. E. Code rules; consequently, Fig. 13 indicates the approximate dial locations for both. A 12 x 6 in. header was made by the Grinnell Co., but was purposely not reinforced, as the Sub-Committee on Welded Branch Connections desired to ascertain if half-size reductions in nozzle connections needed reinforcement. (Previous test data gave some indications that this was probably not necessary.) Figure 14 shows the 12 x 6 in. header set up for test, the dial locations being somewhat relative to the other arrangements. The majority of the dials were placed diametrically opposite each other in order to eliminate, as much as possible, errors in measurement due to shifting of the manifolds on their supports when deflection occurred. All of these headers were arc welded and stress relieved after fabrication. (See Table 2 for data on pipe used.)

Internal hydrostatic pressure was applied gradually in 400-lb. increments by means of a hydraulic displacement machine capable of developing pressures in excess of 50,000 lb. per sq. in., and dial readings were recorded at each increment of pressure until the dials indicating the greatest deflections showed that the pipe material had exceeded the proportional limit. The pressure was then released and the dials and their supporting framework

Fig. 11—8 x 8-In. Reinforced Header Made by The Detroit Edison Co. Set Up for Hydrostatic Test Showing Dial Arrangement

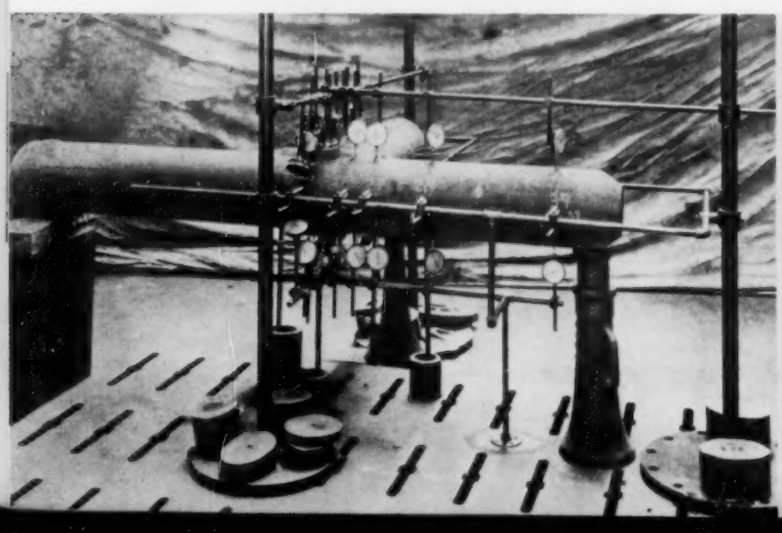
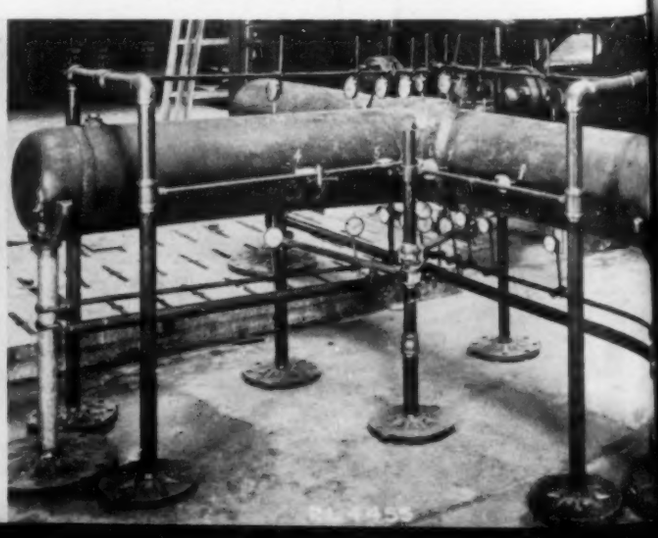


Fig. 12—12 x 12-In. Reinforced Header Made by The National Valve & Mfg. Co. Set Up for Test with Dial Indicators in Place



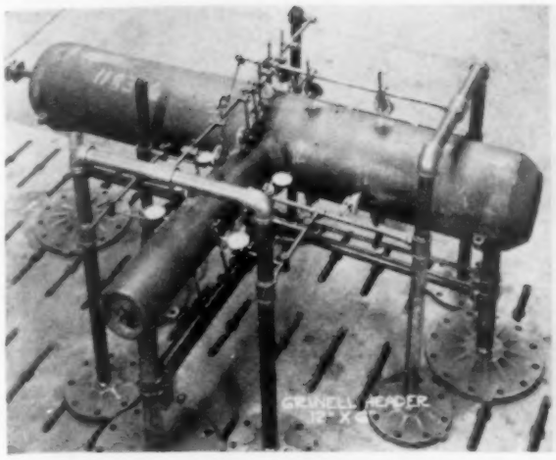


Fig. 14—12 x 6-In. Unreinforced Header Made by the Grinnel Co. Showing Test Set-Up

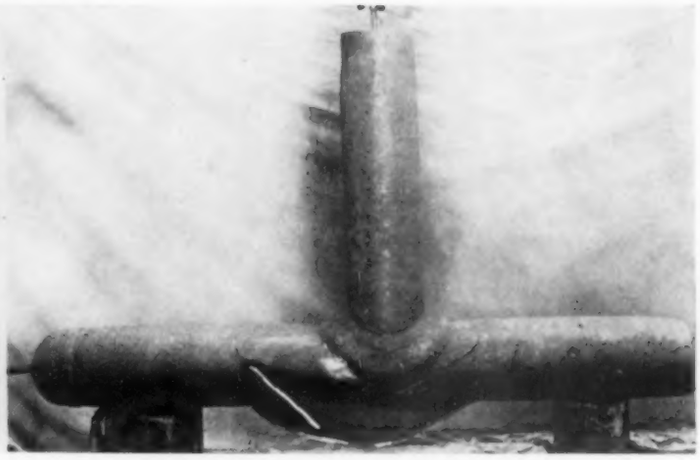


Fig. 15—Failure of 8 x 8-In. Reinforced Header

removed, whereupon pressure was again gradually increased until failure occurred. The 8 x 8-in. and 12 x 12-in. reinforced headers fractured longitudinally immediately below the rings at 8750 lb. and 8000 lb., respectively, as shown in Figs. 15 and 16. The ruptures are typical of pipe failure under hydrostatic pressure, and the bursting pressures are in fair agreement with theoretical bursting pressures based on Barlow's formula, using tensile properties obtained from test bars removed from the headers after the destruction test. This is described in more detail in Table 2. The 12 x 6-in. unreinforced header also failed longitudinally, but the fracture carried into the nozzle in a triangular formation, as illustrated in Fig. 17. The actual bursting pressure is slightly lower than the theoretical, as can be seen from the tabulated data in Table 2.

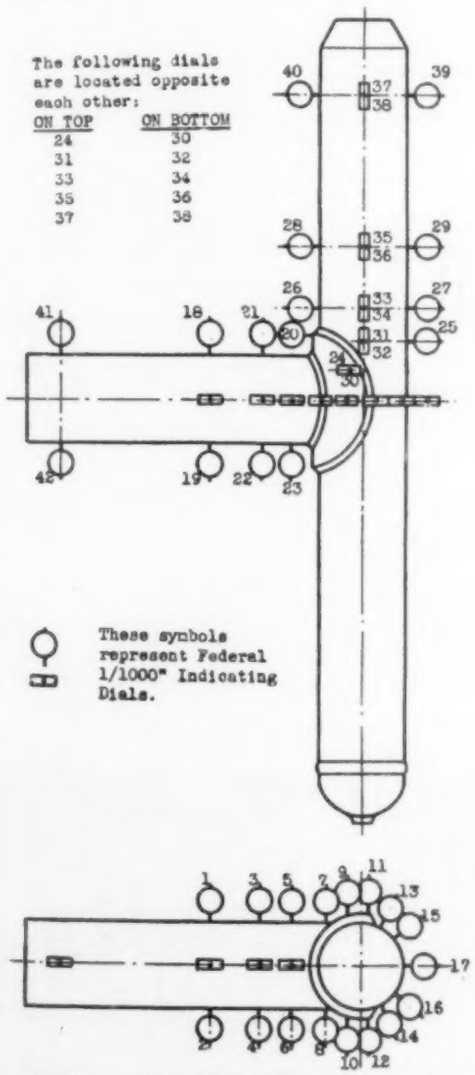


Fig. 13—Locations of Dial Indicators on Headers

The major deflection readings obtained on the three headers are expressed graphically in Figs. 18, 19 and 20. These show that the maximum deformations occurred in the vicinity of the junctions between the headers and their nozzles and indicate what occurs when a circular cross section is deviated, from, thus producing weaker structures to resist internal pressure. While this yielding occurred at the sides of the full-size reinforced connections, the bursting pressures approximate those of straight lengths of pipe without any openings. It appears from this that redistribution of stresses takes place while yielding, and that ring reinforcements proportioned to those employed in these tests will practically develop the full strength of pipe. It also appears that branch connections one-half the size of the header, or possibly smaller, will require some reinforcement. This was taken into consideration by the Sub-Committee in developing reinforcement rules.

Nozzle Connections

Some controversy existed within our own organization, as well as with other fabricators and insurance underwriters on the methods of attaching nozzles to piping. This led us to institute tests on three general types of nozzle attachments to determine the most feasible and acceptable designs. Shortly after these tests had been started a similar discussion arose in the Sub-Committee on Welded Branch Connections and the feeling prevailed that additional tests should be made in connection with those being conducted on header branch reinforcements previously described. Since we were engaged in making an investigation along identical lines, we offered the committee the results of our tests.

A preliminary study was made by fabricating short tees of three different designs of nozzle attachments, using $10^{5}/_{8}$ in. O. D. by 0.875-in. wall thickness A. S. T. M. Designation A 106 Grade A seamless steel pipe, as presented in Fig. 21. The scarfing of the nozzles and the holes in the tubes were accomplished by oxyacetylene cutting torches, the pieces shown in Fig. 21 (*A*) and 21

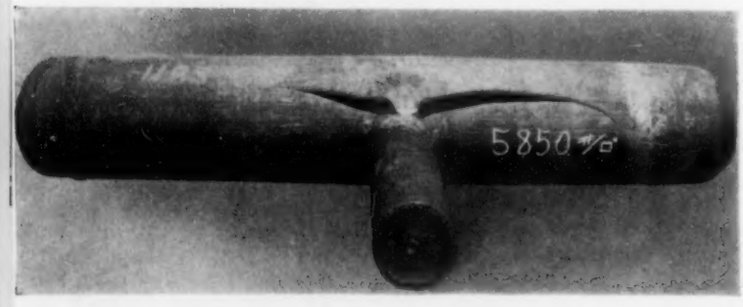
Fig. 16—Failure of 12 x 12-In. Reinforced Header

(*C*) being done manually, while those in Fig. 21 (*B*) were cut in a beveling machine. The assemblies were arc welded by code qualified operators, using all-purpose coated electrodes. After the welding was completed, the tees were cut into sections around the circumference of the nozzles. These were then machined, polished and deep-etched to observe the fusion between the parts joined. Photographs were taken of representative etched specimens removed from the tees at intervals of $22^1/_2°$ on the circumference, starting at the crotch and terminating on the side.

The attachment shown in Fig. 21 (*A*) represented the former practice employed by The Detroit Edison Co.[6,8] The opening in the header is scarfed around its entire circumference but the nozzle is cut square at the crotch and is gradually beveled as the sides are approached, the included angle varying from approximately 60° in the crotch to 120° at the sides. This construction affords a wide welding groove in the crotch, thus aiding the welding operator in obtaining good fusion. Figure 22 shows etched sections from this type of nozzle. A relatively new type of nozzle attachment, popularized by Mr. F. C. Fantz of the Midwest Piping and Supply Co.[7,11] is shown in Fig. 21 (*B*). In this practice the opening in the header is cut straight and the nozzle which sets on top of the header is beveled in the crotch and graduates to a square cut on the sides. The widths of the welding grooves in this design are somewhat reduced (see Fig. 23). The procedure illustrated by Fig. 21 (*C*) is to scarf both the header and the nozzle, thereby providing equal metal thicknesses to be welded, the total included angle increasing from approximately 40° in the crotch to 90° on the sides. The welding groove formed in the crotch is somewhat narrow. Etched specimens are shown in Fig. 24. Our fabricating shop experienced no difficulty in preparing these three types of joints, and in all cases it was possible to obtain acceptable fusion and produce sound welds, as displayed by the etched specimens shown in the illustrations.

Three 8-in. headers with 8-in. unreinforced nozzles were then constructed according to the different practices just described and hydrostatic destructive tests were made to determine if the branch design had any effect on strength. To eliminate, as much as possible, any variation in the physical properties of material, all the test pieces were fabricated from the same length of 8-in.

Fig. 17—Failure of 12 x 6-In. Unreinforced Header



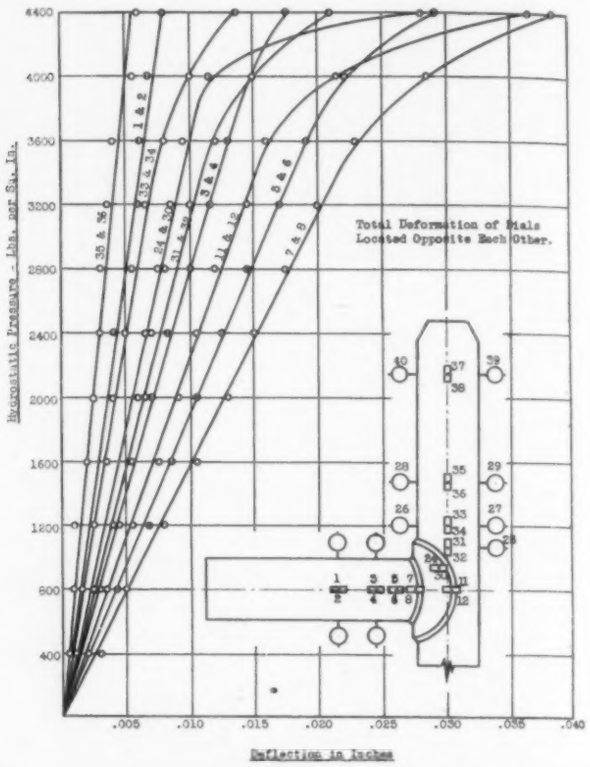


Fig. 18—Diametrical Deflections on Header, Nozzle and Reinforcing Ring Obtained on 8 x 8-In. Reinforced Header

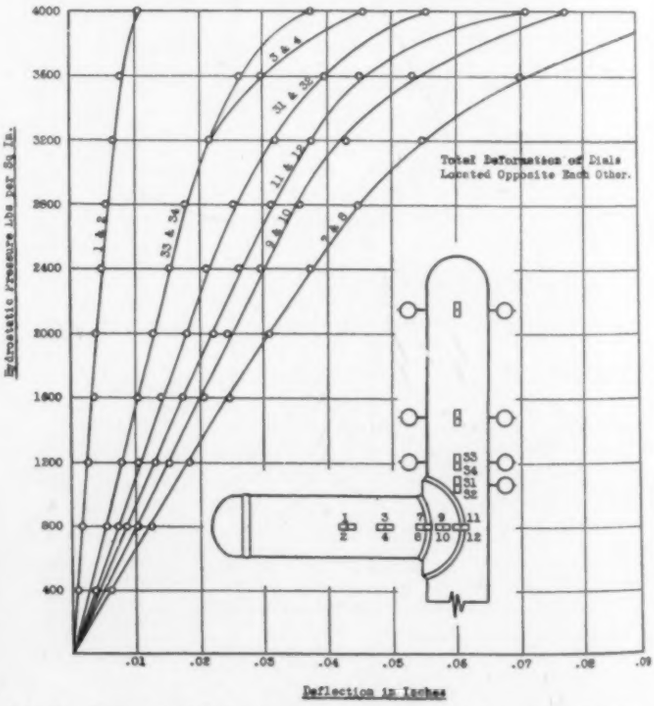


Fig. 19—Diametrical Deflections on 12 x 12-In. Reinforced Header at Various Locations

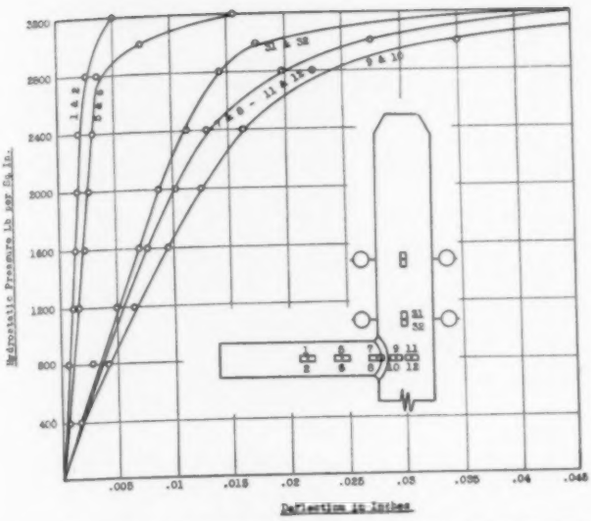


Fig. 20—Diametrical Deflections on 12 x 6-In. Unreinforced Header at Critical Sections

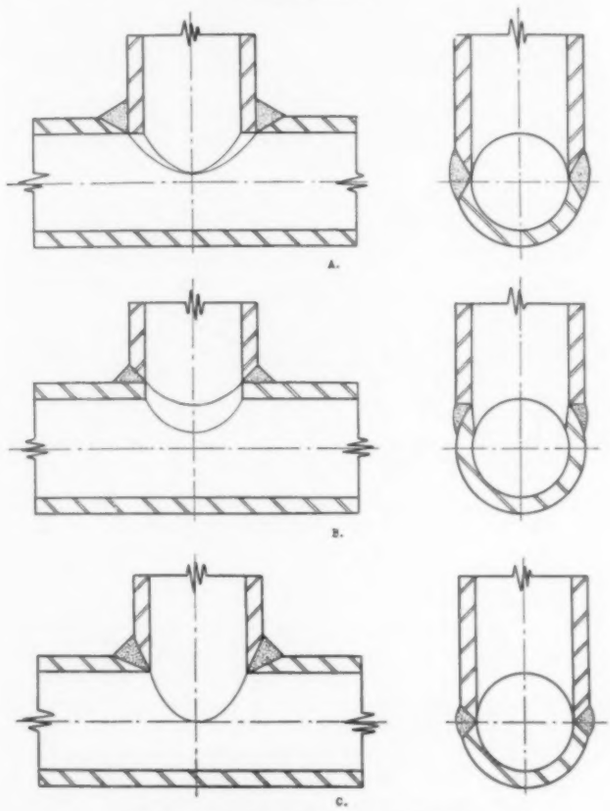
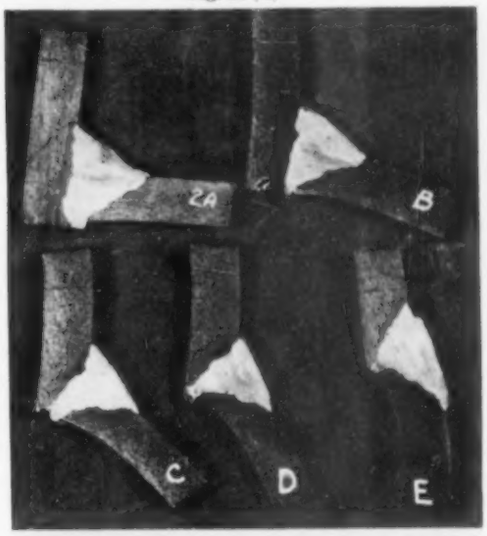


Fig. 21—Types of Nozzle Construction

Schedule 40 A. S. T. M. Designation A 106 Grade A tubing. Subsequent to welding, the headers were stress relieved at 1200° F.

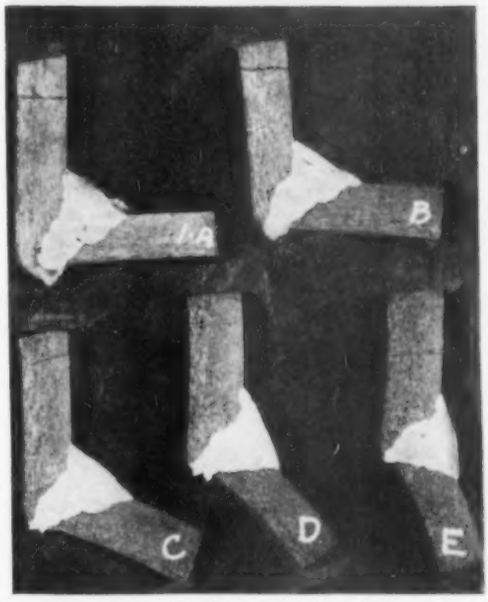
The headers were set up for test in the manner illustrated by Fig. 25 and 34 indicating dials were placed at strategic locations to indicate relative deflections. Test procedure was similar to that employed on the other manifolds, and as pressure was being built up, dial readings were taken at each 200-lb. pressure increment until the proportional limit indicated by most dials had been exceeded. The dials were then removed and the test continued to destruction. The header having a scarfed hole with the crotch of the nozzle cut square (Fig. 21 (*A*)) failed in the nozzle at 6700 lb. per sq. in., as illustrated in Fig. 26. The header having a square hole with the nozzle

Fig. 22—Etched Sections Removed from Nozzle Attachment Shown in Fig. 21 (*A*)



22

23



24

Fig. 23—Etched Sections from Nozzle Attachment Shown in Fig. 21 (*B*)

Fig. 24—Etched Sections Cut from Nozzle Connection Shown in Fig. 21 (*C*)

chamfered at the crotch (Fig. 21 (*B*)) ruptured longitudinally at 6400 lb. per sq. in., as shown in Fig. 27. The header, wherein both the hole and nozzle were chamfered (Fig. 21 (*C*)), failed in the crotch at 6100 lb. per sq. in., as displayed by Fig. 28.

Tensile test bars were cut from the manifolds after the hydrostatic test and these gave average physical properties of 58,650 lb. per sq. in. Using this value in Barlow's formula, the theoretical bursting pressure of pipe such as that from which the headers were made, but not having any openings, would be 6800 lb. per sq. in.

It will be observed that the bursting pressures of the three test headers varied approximately 9%, which may be considered within probable experimental error for investigations of this nature. Each header failed in a different manner, namely, longitudinal rupture along the side of header, fracture in the fusion zone of the weld on the side of the nozzle and extending parallel with the nozzle, and cracking in the crotch. This indicates that the stresses at the time of failure on internal pressure are apt to be at a maximum at any of the three locations. These various types of failure coincide with the results obtained on previous tests made by ourselves and other investigators. Consequently, we feel that the nozzle constructions studied have little or no relation to the ultimate bursting pressures of branch assemblies.

In order to verify the scarfing and quality of the welds at the nozzles of the headers used in destructive testing, and to compare these with the preliminary specimens shown in Figs. 22, 23 and 24, deep etched sections were prepared from each branch assembly. It was observed that the welding grooves in the three types of nozzles apparently did not produce any obstacles to code qualified welders in making the test welds and headers. Acceptable fusion at the bottom of the grooves with but a slight icicle formation, good side wall fusion and sound deposited metal were obtained in all cases, even with rather narrow included angles and variable thicknesses of

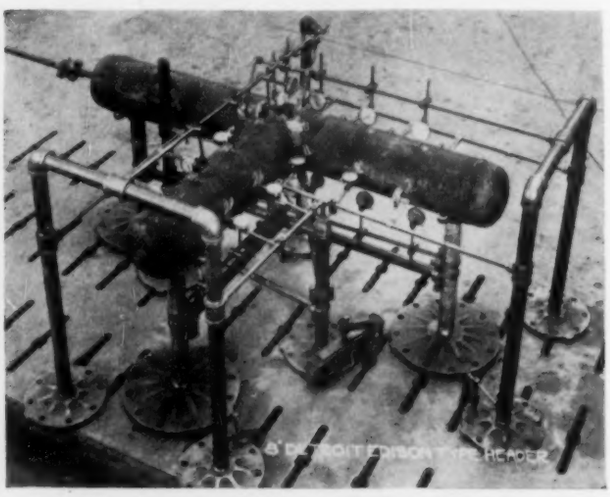


Fig. 25—Typical Test Set-Up for Headers to Study Effect of Various Nozzle Constructions

base metals. Therefore, it appears that any nozzle scarfed in such a fashion to permit complete welding through to the inside diameter of the nozzle or header should be satisfactory, which the Code for Pressure Piping recognizes in its new rules. The type of nozzle attachment to be preferred will depend upon the fabrication equipment available, the cost of preparation, set up, welding and other production problems.

While the latter tests were primarily conducted to study the weldability and strength of three types of

Fig. 26—Failure of Header with Nozzle Attachment Shown in Fig. 21(*A*)

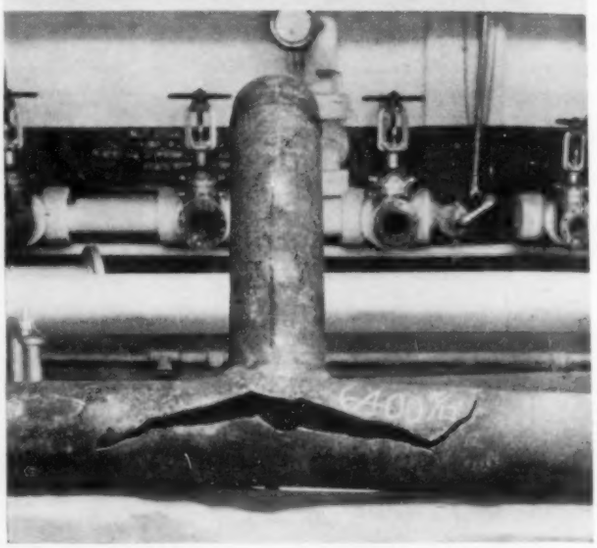


Fig. 27—Failure of Header with Nozzle Attachment Illustrated in Fig. 21 (*B*)

branch connections, the information obtained also presents data on the reduction in strength of headers caused by full-size unreinforced nozzles. This is not quite in agreement with results previously described, wherein reductions of 30% or even greater had been noted in the ultimate failure pressure. The latter tests do not show such magnitudes of reductions in bursting pressures, and we are at a loss to account for these variations. However, the deflection curves recorded from the dial indicators, some of which are plotted in Fig. 29, still indicate the necessity for proper reinforcement to prevent excessive deformation of the flat sides.

The tests reported in this article are necessarily brief, but complete detailed information was submitted to the Sub-Committee on Welded Branch Connections of the

Fig. 28—Failure of Header Having Nozzle Construction Shown in Fig. 21 (*C*)

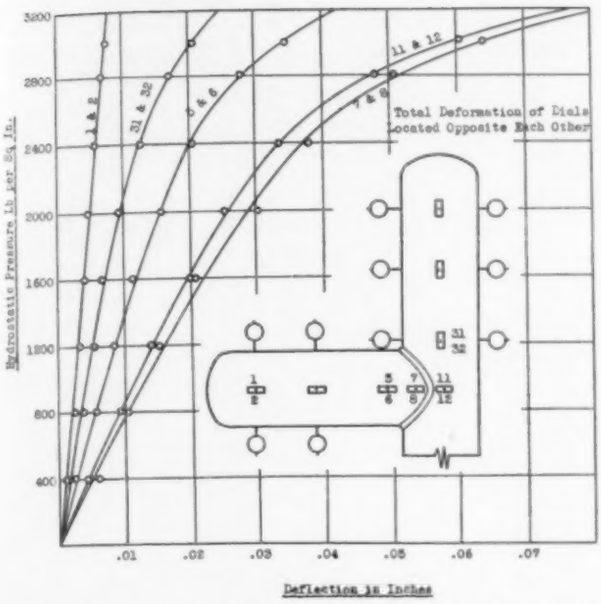


Fig. 29—Typical Diametrical Deflections on Headers with Three Types of Nozzle Attachments

A. S. A. Sectional Committee B-31. These reports, plus some additional data referred to in the bibliography, were carefully analyzed by the committee, and with the co-operation of the Pipe Fabrication Institute's Technical Committee, recommendations on nozzle attachments and their minimum reinforcing requirements were formulated, as will be prescribed in the new revised A. S. A. Code for Pressure Piping. This Code covers all piping used at pressures above 15 lb. per sq. in. and the rules will read substantially as follows, with possible changes in paragraph numbers and editorial corrections.

Chapter 5—Welded Branch Connections and Fabricated or Cast Specials

633. This chapter concerns the methods to be followed in the fabrication of intersecting welded branch connections and is limited principally to those branch connections in which the angle between the outlet and the run is not less than 85 degrees. It also deals with fabricated specials as covered in Par. 635. All the provisions of Chapter 4, so far as they apply, shall be followed.

634. *Welded Branch Connections:* (*a*) Some acceptable forms of joints which have been found to be satisfactory by tests, as shown in Figs. 7 and 8. (Similar to Fig. 21 in article.)

(*b*) The contours of the openings in the run and the end of the outlet shall be such as to make an accurate fit-up.

The edges of the pipe at the roots of the joints shall be not closer than $^1/_{16}$ in. nor more than $^1/_4$ in. except when backing rings are used.

(*c*) A header having a branch or branches attached by welding shall be reinforced to make it equivalent in strength to the computed bursting strength of straight sections of pipe as determined by the formulas for pipe wall thickness given in Sections 1 to 5, incl., of this Code.

The necessity for and the amount of reinforcement required in the crotch section shall be determined by the rule that the area available for reinforcement shall be equal to or greater than the required area as defined as follows: The required area shall be determined as the cross-sectional area of the finished opening in the header, considered as a rectangle whose length is the diameter of the finished opening and whose height is the theoretical minimum wall thickness of the header. The available area included as reinforcement shall be at least the sum of the following cross sectional areas:

1. The cross-sectional area of the fillet welds adjacent to the nozzle and above the outside surface of the header.
2. The cross-sectional area of the branch determined from the minimum thickness or inspection and a height equal to $2^1/_2$ times the minimum thickness of the nozzle wall above the outside surface of the header, or above the outside of the reinforcing ring or saddle, if used.
3. Any additional thickness of the wall of the header above the theoretical minimum thickness required by the wall thickness formulas of Sections 1 to 5, incl., for a distance equal to the inside diameter

Fig. 30—Reinforcing Ring or Saddle Encircling Header Below Nozzle to Reduce Deformation

Fig. 31—Built-Up Collar on Ring to Reinforce Nozzle

of the branch on each side of the center line of the branch.

In case the sum of these available areas is less than the required area, additional reinforcement shall be provided. This additional reinforcement shall be obtained by additional thickness of header wall and/or branch wall, ring, saddle and/or weld metal. See Figs. 9 and 10. (Similar to Figs. 9 and 10 in article.)

The material used for ring or saddle reinforcement may be of specifications differing from those of the pipe, provided the cross-sectional area is made in proportion to the relative strength of the reinforcement and pipe materials at the operating temperature and provided it has welding qualities comparable to those of the pipe.

When rings or saddles are used which cover the weld between branch and header, a vent hole shall be provided in the ring or saddle to reveal leakage in the weld between branch and header and to provide venting during welding and heat-treating operations.

The use of ribs or gussets shall not be considered as contributing to reinforcement of the branch connection. This does not prohibit the use of ribs or gussets for purposes other than reinforcement.

The hole to be compensated for by reinforcement shall be measured on the diameter of the outlet parallel to the axis of the run.

Fillet welds used in attaching the reinforcement shall be full fillet welds.

Reinforcing rings and saddles shall be accurately fitted to the parts to which they are attached. Figures 9 and 10 illustrate some acceptable forms of reinforcement. (Similar to Figs. 9 and 10 in article.)

(*d*) Branch connections attached at an angle less than 85 deg. to the run become progressively weaker as the inclination becomes less. Any such designs must be given individual study and sufficient reinforcement must be provided to compensate for the inherent weakness of such construction. The use of encircling ribs to support the flat or re-entering surfaces is permissible, and may be included in the strength calculations.

635. *Fabricated and Cast Specials:* (*a*) Fabricated swages, orange-peel bull plugs, segmental elbows and other special fittings may be formed from pipe or plate material and welded in accordance with the general requirements for welded joints specified in this section. Design shall be such that the fitting will be equivalent in strength to the computed bursting strength of a straight section of pipe as determined for the service conditions by the formulas for pipe wall thickness given in Sections 1 to 4, incl., in this Code. The inherent weakness of such designs shall be taken into account in establishing the service conditions under which they may be used.

(*b*) Cast special fittings with welding ends shall conform to material requirements of A. S. T. M. Specifications A 216 or A 217, and shall be designed in accordance with requirements of American Standard B16e, or Par. 634 if practicable. Where rules of American Standard B16e are applied in the design of such fittings, the shape factor employed in determining minimum wall thickness may be omitted for the cylindrical or tapered ends. When welding ends of castings are machined both inside and outside and carefully inspected, the quality factor at the welding ends may be taken as 100 per cent, but in no case shall the thickness of the welding end be less than the wall thickness of the mating pipe.

As mentioned previously, the new Code rules are minimum requirements and correspond quite closely to those prescribed in the A. S. M. E. Unfired Pressure Vessel Code, except that no 2-in. deduction in width of cross-sectional area of the finished opening is permitted. Since the A. S. M. E. Code regulations were intended to be applicable only to nozzles not greater than 60% of the shell diameter, the Piping Code rules are virtually an extension of the former to include branch connections of full size. While all of the tests show that ring reinforcements provide adequate strength to meet most conditions it does appear that for full-size and possibly one-size reduced nozzles, additional reinforcement should be considered, especially where the service is as severe as that encountered with high-temperature conditions or pulsating loads. This can be accomplished by having the ring or saddle extend around the header, tapering from the top at the nozzle to the bottom, as shown in Fig. 30. A collar, such as illustrated by Fig. 31, should also be incorporated on the nozzle, which could either be integral or built-up with the saddle. Such a construction, no doubt, would amply reinforce all the highly stressed areas. A somewhat similar design was also suggested by Mr. McCutchan in his article entitled, "Fabrication Details for High Pressure and Temperature Piping at Delray," published in *Heating, Piping and Air Conditioning*, April 1939, excepting that instead of a collar on the nozzle, wedge-shaped side plates were built on the flat sides of the nozzle from the ring.

Acknowledgments

The author wishes to express his appreciation for permission from the Pipe Fabrication Institute to publish the data obtained from the tests they made possible and to thank The Detroit Edison Co., National Valve & Mfg. Co., Grinnell Co. and the National Tube Co. for their kind cooperation in submitting test headers and material, also the members of the Sub-Committee on Welded Branch Connections of the A. S. A. Sectional Committee B-31 for the advice they rendered in outlining the tests. The splendid assistance of the staff of the Crane Co. Research Laboratories is appreciated and gratefully acknowledged.

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Report of Subcommittee on

THERMAL STRESSES AND SHRINKAGE IN WELDED SHIP CONSTRUCTION*

FOREWORD

At a meeting of the Committee on Welding in Marine Construction held in April 1935, it was pointed out that the phenomena of shrinkage in welded joints created a most important problem in welded ship construction: first, as a matter of dimension, and second, with regard to the stresses which would be set up in the structure. In the discussion which followed, it was felt that it might be necessary to develop standard rules of procedure to avoid serious trouble in service. As a result, the Chairman appointed a Subcommittee to assemble available data from previous work and to investigate the general problem of thermal stresses in welded ships.

The members of the Subcommittee are directly involved in this works each faced with the solution of urgent problems at their individual plant, which have been brought about by the rapid expansion of welding. It has been impossible for the Committee as a group to undertake the study of its topic as one for research leading to the development of recommended practice in advance of the application to actual ship construction. Rather, each yard has worked out its own problems and the Committee has served as a clearing house of information springing from practical and service experience.

On October 26, 1939, the Subcommittee presented a complete report in preliminary form to the Committee on Welding in Marine Construction for their general criticism and comment. Following receipt of written comment from practically all members of the Main Committee, the Subcommittee presented its final report, which was approved unanimously by the Main Committee at a meeting held on October 21, 1940.

I—INTRODUCTION

In the field of naval ship construction, the Bureau of Ships (formerly the Bureau of Construction and Repair) has developed, during the past five years, detailed specifications covering the applications of welding, particularly in regard to the procedure to care for the effects of thermal stresses and shrinkage. In merchant ship construction, the regulatory bodies have, speaking generally, been much less specific in regard to this phase in their written rules and specifications, dealing in the results to be obtained rather than in specific methods of procedure. A question of primary importance is, therefore, the necessity for more or less elaborate precautions to prevent or mitigate possible adverse effects of welding shrinkage. If such steps are not required or may be simplified, naval construction will benefit by the elimination of much costly procedure coupled with a reduction in time of building welded ships. Ship welding has had extensive service trial over a period of years with a truly remarkable record of satisfactory performance. More will be said of the matter of service failures later in this report but it may be stated that many ships whose construction in whole or in part violated many principles of stress-free welding procedure have undergone extraordinary sea tests without failure. It is therefore pertinent to reexamine the theory and logic of some of these principles if for no other reason than to account for this excellent record.

The general topic of thermal stresses and shrinkage resolves itself into three main sub-divisions:

I. The loss of original dimensions of welded parts or assemblies, which is reflected in the loss of the principal design dimensions of the ship if no allowance is made.

II. Distortion or the loss of shape of individual parts or assemblies. This includes warping and twist, the appearance of buckles and wrinkles in plane surfaces, or the rise of bow or stern.

III. Residual or "locked-up" stresses, either in the welded joint or in the structure due to shrinkage in proximity to the welded joint.

II—LOSS OF DIMENSION

The most obvious result in welded construction, which does not occur at all or only to an inappreciable degree in other forms of jointing, is loss of dimension due to shrinkage. Further, this loss of dimension is encountered in two different forms. When a joint is made between two individual parts, there is shrinkage of the filler metal, added in the molten state, which tends to draw these parts together. If one part is being attached to the other, that is, when a weld is made to a continuous or passing member, there is also shrinkage in the vicinity of the weld which is reflected in the shortening of the passing member. Applied to ship structure, these two forms can be represented by (*a*), butts or seams in shell plating, and (*b*), the attachment of framing to the shell plating. Unless compensation is made for both forms, the completed shell will be less than its original designed length.

The Subcommittee has collected a great deal of test data as well as records of measurement on full-size or actual ship structures. In addition, a very considerable amount of data has been published and a notable collection or summary of these data is available in an A.W.S. Research Supplement.[1] Analysis of all this information reveals so wide a discrepancy

* Prepared by Committee on Welding in Marine Construction

Approved by Executive Committee July 23, 1941

[1] Shrinkage Distortion in Welding, by W. Spraragen and G. E. Claussen, AMERICAN WELDING SOCIETY JOURNAL, Research Supplement, July 1937.

in shrinkage between similar joints as to render a summary or tables of predicted shrinkage valueless. The data on record also show wide differences between small and large-scale tests. It must be concluded that too many variables enter this phase of the problem, many beyond the control of the welding operator or shipbuilder.

The problem of dimension is not, however, of primary importance. Where no correction has been made, shrinkage in the length as high as 6 inches in vessels less than 150 feet long has been reported. Such loss is actually of little moment in so far as speed and power are concerned and generally is of concern only in the loss of capacity. In the construction of larger ships, some means of correction has invariably been employed so that the loss in dimension has generally been insignificant.

Among the corrective measures which have been employed in ship construction are (1), the use of expanded scales, (2), the use of excess length or allowance over mold loft or drawing dimension, and (3), "lift from ship" correction.

The use of the expanded scale is borrowed from the pattern shop and foundry. Since a finished casting is smaller than the pattern molded in the sand, an expanded measuring stick is used in the construction of the pattern which makes allowance for the shrinkage per foot of the particular metal being used. The application of this method to a welded ship assumes that welding shrinkage, like that in the casting, is relatively uniform throughout. Unfortunately, this is rarely if ever true. Not only are we faced with wide variations in shrinkage of similar joints as noted above, but there are also wide differences in the application and amount of welding in many different parts of the structure. A deck, for example, may be transversely framed whereas the shell plating in the vicinity of that deck may be largely longitudinally framed. One may consist of considerably heavier plating than the other although the attachment of framing may be made with welds of similar or identical size since the strength of the connection desired is not necessarily a function of plate thickness. It is obvious that the same expanded scales cannot be applied to both structures. Furthermore, in shipbuilding, the use of scales, and the measuring and setting of various parts, is not restricted to any one operation or department. Correlating the proper scales with regard to varying ship structure throughout the progress of material from storage yard to ways has generally proved too complicated a problem for the benefits derived and, although actually tried in practice, this method of correction, as far as the Subcommittee is aware, is generally no longer in use.

A method in common use is to add an arbitrary allowance or excess to the length and width of parts subject to welding shrinkage. As a general rule this allowance is considerably more than the shrinkage actually expected and the excess is then removed after as much shrinkage as possible has taken place. Only where it is impossible to leave such excess is it wise to allow the exact shrinkage predicted. The excess or allowance method may be made on all parts and ships' dimensions corrected at intervals, thus allowing a considerable amount of material to be used without flame cutting or chipping in erection.

A third corrective measure is to leave selected parts of the structure to be measured or "lifted" from the ship after adjacent structures are completely welded and shrunk to the final dimension.

III—DISTORTION

Distortion, particularly when localized in the form of buckles in flat or but slightly curved plates, is an especially troublesome problem to the shipbuilder. While it may be frequently argued that such distortion has little or no effect on the strength or service life of the ship, the unsightliness of such distortion coupled with the complication in the attachment of other parts to warped structure creates a major problem. Where excessive distortion occurs and is unacceptable, the warped part is straightened by the application of heat or mechanical work, usually at great expense. In ships with light scantlings, the cost of straightening has frequently exceeded the cost of fitting and welding the structure. Viewed from the angle of cost, appearance, or utility, prevention of distortion is so much to be preferred to its correction that an extensive study of this particular problem is warranted.

In the field of preventive measures, shipbuilders have experimented with all manner of methods, the principal ones of which may be classified as follows:

(*a*) *Pre-springing or initial distortion*

In its simplest application, this method consists of mechanically setting or bending a part in an opposite direction to which warpage is expected so that the effect of welding is to restore the part to its desired shape.

(*b*) *Strong-backs or jig methods*

The size and variation of ship structures generally preclude the use of jigs of the type frequently applied to small machine or sheet metal assemblies. A variation which is applicable to large structures is the use of strong-backs and temporary stiffening by which the structure is given increased resistance to distortion but which are removed after the welding has been completed and cooled.

(*c*) *Drum-heading*

This classification refers to a method frequently used on large areas where the boundaries have a large degree of permanent or temporary restraint. The effect of the welding operations on this plating tends to shrink it in size and, as a result of the boundary restraint, the plating is kept flat.

(*d*) *Extent of tacking, and wandering sequence*

This method is a variation of the drum-head or restraint method. If a considerable section of structure is heavily tacked or if a wandering sequence is employed which involves the virtually simultaneous completion of all welded connections, as opposed to successive completion frame by frame, there may be a considerable reduction in distortion due in part to restraint and part to reduction in local heating.

(*e*) *Design*

The importance of design in reducing distortion cannot be over-emphasized. In this classification falls the use of a minimum amount of filler metal, suitable arrangement of joints to avoid localized areas of extensive

be measured or "lifted" from the ship after adjacent structures are completely welded and shrunk to the final dimension.

shrinkage, elimination of shift of butts in all-welded construction, etc. It is not always possible, however, for the designer to obtain such ideal conditions, since many basic specifications require modification and, further, a large proportion of ship draftsmen have not yet had an opportunity to familiarize themselves with the effect of welding shrinkage.

Corrective measures can be roughly classified as follows:

(*a*) *Shrinkage*

While varying in detail, this method consists of alternative heating and cooling, frequently accompanied by hammering or mechanical work, thus shrinking excess material in a wrinkle or buckle.

(*b*) *Shrink welding*

This is a variation of (*a*) above, in which the heat is supplied by running beads of weld metal on the convex side of a buckled area. On cooling, the combined shrinkage of the heated parent metal and the added weld metal removes the distortion. The beads of weld metal may then be ground off if a smooth surface is desired.

(*c*) *Added stiffening*

This method, which is applicable only to plate panels, consists of pulling the plate into line by strong-backs and welding additional stiffening to the plate to make it retain its plane. In addition to the stiffness added, there is also benefit from shrinkage in the connecting welds.

It is important to note that certain of the preventive measures, notably drum-heading, extensive tacking, and the wandering sequence as well as the corrective methods of torch shrinking and shrink welding, are directly opposed to the theory that the structure should be free of residual stresses. The success of these measures is due to the fact that opposed and equal stresses are set up. Taken rather broadly, structures tend to relieve themselves by distortion. It follows that its prevention, or correction, means the creation of residual stresses in many instances.

IV—RESIDUAL OR "LOCKED-UP" STRESS

Welding procedure, by which is generally meant the sequence of operations in regard to both erection and welding, has been referred to above in connection with the control of shrinkage and distortion. It also has been closely studied and developed for two other purposes: first, to assure completion of a weld without total or partial failure, i.e. cracking; and second, to leave structures not adaptable to furnace stress relief in a satisfactory condition for service.

The satisfactory behavior of welded structures in service is predicated upon sound welds. The obtaining of sound and properly-fused welds, free of checks and incipient cracks, as well as slag, porosity, blow-holes, and the like, is therefore of major importance. To this end procedure includes much more than sequence of welding; in fact, other factors such as preheat, the continuity of the welding operation, peening, and an endeavor to assure a uniform distribution of stress over the joint are often of equal importance.

sized. In this classification falls the use of a minimum amount of filler metal, suitable arrangement of joints to avoid localized areas of extensive

Procedure also shares importance with other factors in this matter of obtaining sound welds, namely, adequate inspection, suitable equipment, the proper training and qualification of operators, and not least important, the accessibility of the joint. Even the most carefully developed procedure cannot be depended upon to compensate for deficiencies in the other requisites for sound welds.

The reduction or elimination of residual stresses in the completed structure by means of a definite procedure intended to permit unrestrained shrinkage is the point which is generally given primary importance and on which there are, perhaps, the widest divergence of opinion and elements of controversy. Ship structures generally, with the exception of individual weldments for stern posts, etc., must be placed in service in the as-welded condition. The effect of residual or locked-up stress and the necessity, if any, for its consideration are therefore of primary importance and have received major consideration by the Subcommittee.

"Stress-free" procedure methods, which were referred to at the beginning of this report, are based on two fundamental assumptions:

(*1*) That residual or locked-up stresses can be avoided or minimized by a welding procedure in which no positive external restraint prevents free shrinkage.

(*2*) That these residual stresses are always detrimental and should be avoided at all costs.

Discussing these assumptions in order:

There has been a considerable volume of test data published in recent years on shrinkage stresses in the vicinity of welded joints of various types. Examination of these reports leads to the conclusion that the stress distribution in and near a welded joint is exceedingly complicated and indeterminate. Due to the nature of the process, involving high temperatures, there is plastic flow as well as elastic movement in adjacent parent metal. Time and temperature relations are affected by a large number of variables, some completely beyond the control of the operator, and others which vary widely with different operators. In most shipwelding processes, the filler metal is added literally drop by drop with that first deposited cooling more or less rapidly. Even in the highest speed automatic processes, with the possible exception of flash welding which is not applicable to ship joints in general, a large part of any welded joint has time to cool before completion of that joint and obviously supplies a high degree of restraint. Therefore, we may expect to find, as reliable investigations substantiate, the fact that high residual stresses exist irrespective of any external restraint.

The addition of external restraint may or may not increase the stresses in and near the joint. The lack of restraint probably prevents stressing the member generally, i.e. at a distance from the welded joint. If, however, stresses well beyond the yield point, resulting in permanent set exist in or adjacent to the welded joint, it appears illogical to employ elaborate means to reduce elastic stresses at points between welds.

The second assumption, namely that residual stresses are always detrimental and should be avoided at all costs, may also be seriously questioned both in theory and from a practical standpoint. Residual stresses compose an internal force system which obviously must be in equilibrium. When such a system is subjected to externally applied loads, there is no

simple addition to like forces from which to conclude that some local point may be overstressed. For example, externally applied loading in tension cannot be additive to residual stresses of like sign until the balancing compressive stresses of the system in equilibrium are overcome. This principle is well established as in the case of pre-loaded bolts in cylinder head joints and has been demonstrated in a variety of test devices.

A rolled shape, as delivered from the steel mill, is in a similar state of locked-up stress. Investigators have measured residual stresses up to the yield point existing in rolled sections.[2] An indication of these stresses is the warpage of an I-beam when the web is split to form two T-sections, yet these beams are used safely under the assumptions of our beam formulas.

A further consideration which reduces the importance of residual stresses is the property of shipbuilding steels, all of relatively high ductility, to elongate under stress. Although the yield point is reached in comparatively slight extension, considerable elongation is required before such steels reach the point of failure. Before local points reach any appreciable part of this elongation the load has been re-distributed with adjacent material assuming a larger proportion. This principle has been used for years in the "stretcher-leveling" of steel plates. In this method, the tendency of a plate to buckle and warp after rolling due to residual rolling stresses is removed by stretching the plate beyond its original elastic limit, thus re-distributing the stresses in a more uniform manner.

There is considerable evidence that residual stresses, whether induced by cold work such as rolling, bending, or flanging, or by hot work, either welding or shrinking, tend to distribute themselves and to reduce peak values particularly when subjected to external loading. I-beams which have been allowed to season do not warp on splitting to the same degree as beams used on receipt from the mill. Castings are frequently allowed to season, at ordinary temperatures, for the same reason. Stress-relieving by furnace treatment is in part an accelerated seasoning process. The critical time, therefore, in a welded structure is a period of somewhat indeterminate length beginning immediately after the welded joint is made. If exposed to sudden changes of temperature which induce highly localized stress before reasonable seasoning can take place, there is the possibility of failure. There have been few such cases in shipbuilding; nevertheless, they are not unknown and appear to account for the majority of plate or joint failures particularly during the winter months in northern yards.

A ship can be regarded, due to its water-tight compartmentation, as a series of tanks or pressure vessels. So regarded, however, it would be classed as a thin-walled pressure vessel. In pressure vessel practice, it is well established that the necessity for stress relieving and the avoidance of cumulative residual stress of a probable biaxial nature, is a function of relative wall thickness compared to tank dimension. These ratios in a ship are so low that, by pressure vessel standards, stress relief is wholly unnecessary except in a few heavy weldments forming such items as stern post, rudder post, etc.

[2] "Determination of Initial Stresses," Josef Mathar, A.S.M.E. Transactions, 1934; also A.W.S. Journal, July 1934.

The Subcommittee believes that it is impracticable to set a limit on thickness of plating in which the presence of residual stresses is of minor importance. Experience in welded ships indicates that plates up to 1 in. thick may be welded successfully although restrained from free shrinkage. The rigidity of a structure, however, depends not only upon the thickness of plating, but on the relative degree or stiffening, the size and relative dimensions of unsupported panels, and many other factors which make generalization impossible.

From the purely practical standpoint, it may be pointed out that welded joints in large, and frequently complicated ship structures, can rarely be made under conditions which permit the uniformity of shrinkage, irrespective of any external restraint, that has been so frequently assumed. It can also be stated that such structures cannot be erected, regulated, and prepared for welding without an indeterminate degree of restraint. Regardless of the methods employed, it is a matter of practical experience that few structures approach the degree of freedom assumed in theoretical discussions of "stress-free" procedure. To avoid excessive distortion and subsequent straightening, considerable use is made of the step-back, extensive wandering, and berth systems of welding. It cannot be argued that these procedures, especially the latter two, permit the freedom of relative shrinkage which is assumed. The use of tack welding and bolting, as actually carried out in practical shipbuilding, also denies such freedom of relative movement.

Mention has been made of the use of shrinkage methods to correct distorted structure. It appears highly illogical to take elaborate precautions to prevent or reduce residual stresses only to employ means in fairing the finished structure which depend for their effectiveness upon setting up residual stress.

It is likewise a matter of practical impossibility to complete all operations of welding large structures in perfect sequence. In new construction there are frequent closing or final joints which can be made only after previous work has reduced or entirely eliminated freedom to shrink. Moreover, in repair work as well as in major alterations to existing ships, it is impossible to avoid "locked-up" conditions. The vast number of these jobs, ranging from the replacement of a damaged shell plate to the extensive rebuilding of a ship, which have been accomplished over the past fifteen years and which have successfully stood up under all manner of service conditions is ample evidence that we depend not upon the elimination of residual stresses but upon the ability of the material to accommodate such stresses.

The considerations discussed in the foregoing have been based upon (*a*), service experience and observation, (*b*), reference to laboratory and test work by various investigators as published in the technical literature, and (*c*), tests and experiments made by individual shipyards in the course of their work. Much can be learned from the analysis of failures, perhaps even more than from wholly successful operations. In this phase of its work, however, the Subcommittee has encountered the usual difficulty in that failure of any structure involves the interests of so many individuals or groups that it is rarely possible to make an unbiased analysis of cause and effect, particularly for publication. *So far as the Subcommittee is aware, service failures of ship structure in which welding shrinkage has*

items as stern post, rudder post, etc.

[1] "Determination of Initial Stresses," Josef Mathar, A.S.M.E. Transactions, 1934; also A.W.S. Journal, July 1934.

played a possible part have been rare and, in comparison to the extent of work accomplished, insignificant. It is regrettable, nevertheless, that these instances, which might clarify much misunderstanding, have not or cannot be made available for unprejudiced analysis.

Shipbuilders in recent years have demonstrated that the welded ship suffers but little handicap in building cost or time where the structure is not complicated, or where the step by step, stress-free procedure is not rigorously applied. The importance of a reasonable and logical viewpoint toward residual stresses lies in removing these handicaps, so generally claimed in naval vessels and in more complicated type of merchant ship.

V—CONCLUSIONS

The Subcommittee, as individuals, concur in the following:

1. That the phenomenon of shrinkage is complicated by so many factors beyond the control of the shipbuilder that tables of predicted shrinkage are of no value.
2. That the detrimental effects of correcting distortion subsequent to the completion of the structure may be as serious as the residual stresses involved in most methods of prevention.
3. That residual stresses in ships, incident to joints welded under various and indeterminate degrees of restraint, do not appear to affect the strength of the structure in service provided:
   (*a*) The filler metal is deposited by electrodes conforming to Grade E6010 of the filler metal specifications or equivalent process giving a similar degree of ductility.
   (*b*) The structural material is of proved welding quality.
   (*c*) Due care and diligence is observed in preventing, or detecting, stress cracks during and immediately following the welding operation.

VI—APPENDIX

The Subcommittee acknowledges with thanks the many comments and suggestions received from the membership of the Society's Technical Committees. Of these, possibly the most pertinent is the criticism that conclusion 3 (*b*) is not fully defined. So far as the Subcommittee is aware, welding quality has not been accurately or fully defined by any competent authority. A great deal of work has been done and a great deal of material has been published on this subject. In so far as ship construction is concerned, experience indicates that the steels in common use are of welding quality within the meaning of the Subcommittee's conclusions.

Since the comment of Professor Mortimer F. Sayre, of Union College, Schenectady, New York, has direct bearing on this matter of welding quality as well as upon other conclusions of the report, it is given below:

"Probably wisely, the report emphasizes the conditions under which residual stresses are not dangerous, rather than those under which they are dangerous. The reverse side of the picture could possibly tentatively be pictured as follows—and I offer this statement partly in order to elicit criticism with view to modification:

"In absence of defective workmanship residual stresses whether due to thermal or other causes become dangerous only if:

1. The material is brittle, with high resistance to plastic flow as compared to its resistance to cohesive failure.
2. The material is in a notch sensitive state, possibly measurable by unduly low notch impact value.
3. The piece is so thick and so rigid that it maintains its shape even after very high internal stresses have developed. This rigidity prevents plastic flow from occurring, sufficient to relieve these stresses.
4. The stress distribution is such that localized areas of three-dimensional tensile stress can be developed. At these points shearing stress is absent or negligible in amount, and so plastic flow with resulting relief from excessive stress does not occur.
5. Fatigue failures may occur in structures at points of alternating stress. Evidence seems to suggest however that in absence of the stress conditions noted in (3) and (4) above, failure will be due to the presence of stress raisers rather than to the presence of initial stresses."

PERSONNEL OF SUBCOMMITTEE ON THERMAL STRESSES AND SHRINKAGE IN WELDED SHIP CONSTRUCTION

H. W. Pierce, *Chairman*.....New York Shipbuilding Corp.
D. Arnott.....American Bureau of Shipping
A. G. Bissell.....Bureau of Ships, Navy Dept.
C. W. Bryan.....Federal Shipbuilding & Dry Dock Co.
R. H. Cunningham.....Newport News Shipbuilding & Dry Dock Co.
E. D. Debes.....Bethlehem Steel Corp.
T. M. Jackson.....Sun Shipbuilding & Dry Dock Co.

Welding Metallurgy

VOLUME II

By O. H. HENRY and G. E. CLAUSSEN

A series of lectures prepared for presentation in a fundamental course of metallurgy and metallography at Polytechnic Institute of Brooklyn under the joint auspices of the Institute and the New York Section of the AMERICAN WELDING SOCIETY. To be published serially in The Welding Journal. The lectures are reproduced in attractive booklet form, copiously illustrated—357 pages—with imitation black leather covers. Volume 1 consists of the first series of 10 lectures given by the New York Section in cooperation with the Polytechnic Institute of Brooklyn last year. Volume 2 includes the series of lectures given this year. The price of the book containing both volumes is $1.50 per copy. Special prices can be arranged for quantity lots of 50 or more.

Part VIII—Preheating and Stress Relief

Preheating involves raising the temperature of steel above the temperature of the surroundings before welding. The entire part may be heated or, if local preheat is called for, only the vicinity of the weld is heated. Sometimes post-heating, heating the weld immediately after it is completed, may be substituted for preheating. The requisite preheating temperatures depend on steel, rigidity and welding process; they vary from 100 to 1200° F. It is important that the part is preheated to the correct temperature, which may be estimated by many methods; for example, surface thermocouple, colored chalks that change color at known temperatures, pellets that melt at known temperatures, and the charring of a splinter. The best method of insuring that the preheating temperature is correct is to preheat the part in a furnace held at the desired temperature. Allowance always must be made for the cooling of the part after removal from the furnace. For this reason the furnace should be at a temperature higher than the minimum temperature below which trouble is known to ensue. Welding should be discontinued before the minimum safe temperature has been reached. There are occasions when too high preheating temperature may be as disastrous as too low, for example, a complicated part without internal strutting may collapse, or the heat from the part may prejudice the operator's ability to produce a sound weld.

Preheating may be used for a number of reasons among which are the prevention of hard cracks, hard zones and shrinkage stresses and the reduction of distortion. Heat treatment, on the other hand, cannot prevent cracks that occurred during welding. However, it softens any hard zones and relieves shrinkage stresses, the heat-treated part may be suitable for service that might cause failure of a part that was merely preheated during welding but not heat treated afterward. Heat treatment signifies heating the part to a relatively high temperature, 1100° F. or over, after all or part of the welding is completed. Preheating, on the other hand, signifies heating the part to a relatively low temperature before welding is begun. It is rarely practicable to weld the part at the temperature of heat treatment.

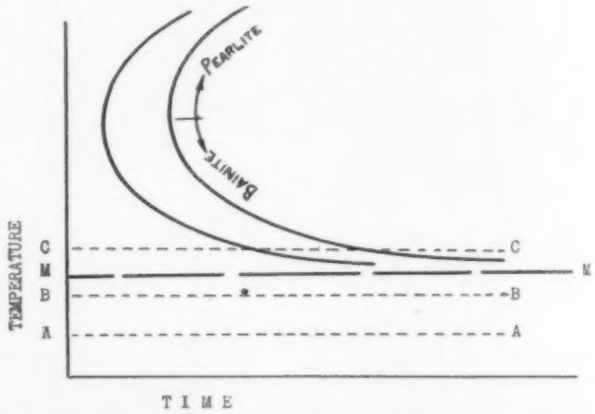

Fig. 54 (a)—Preheat Temperature in Relation to the S-Curve. The Dotted Lines Represent Different Preheating Temperatures

Preheating

Whatever other effect preheating may exert, it is a universal rule that it lowers the cooling rate after welding, as explained at the end of Part I, Vol. I. For a given condition of welding (current, welding speed, etc.) cooling rates will be faster for a weld made without preheat than with preheat. The higher the preheating temperature, the slower will be the cooling rates after the flame has passed. Besides reducing the temperature gradient, which is the principal factor governing cooling rate, preheating lowers the thermal conductivity of iron. The thermal conductivity of iron at 600° C. is only half the thermal conductivity at room temperature. Low thermal conductivity necessitates slow withdrawal of heat from the welded zone, and correspondingly slow cooling rates. Further, an increase in base metal temperature sometimes increases the "hotness" of the weld puddle in arc welding. As a result beads deposited on plates preheated to 300° or 600° C. may be more concave or spread further than on plates without preheat.

Reduction in cooling rate by preheating increases the time spent by the heat-affected zone in the temperature range 500–650° C. and therefore, promotes the transformation of austenite to pearlite (ferrite + carbide) instead of to martensite, Fig. 9. The preheated weld is less likely to have hard zones than without preheat.

Fig. 54 (*b*)—Austenite Grains with Twins

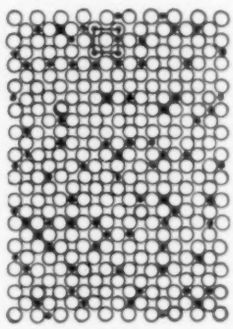

Fig. 54 (*c*)—Austenite Crystal Lattice Showing Carbon Atoms (+) in Interstitial Positions (Interstitial Solid Solution)

Open circles are iron atoms. The carbon atoms are not combined as separate crystals of Fe_3C. (Rollason).

Despite the slower cooling rate provided by preheating, the steel to be welded may yet fail to transform to pearlite during cooling. If the preheating temperature is relatively low, B in Fig. 54(*a*) contrasted with room temperature A, the heat-affected zone close to the weld may transform to martensite. It appears to be a characteristic of martensite in the higher-carbon steels (0.6% C or over) which we are safe in assuming applies to lower-carbon steels that the percentage of austenite that transforms to martensite increases as the temperature decreases. In Fig. 54, M is the highest temperature at which austenite changes to martensite during cooling. However, at temperature M only a very small percentage of the austenite may change to martensite. The small percentage of martensite appears instantly as soon as M is reached during cooling, but little more martensite is formed if the temperature is held at M. Lowering the temperature to B causes further transformation of austenite to martensite, the reaction again stopping when a critical percentage of austenite has changed to martensite. During further cooling to room temperature, A, nearly all of the remaining austenite changes to martensite. It is not unusual to observe considerable percentages, say 10%, of austenite in tool steel that has been quenched to room temperature.

Fig. 54 (*d*)—Microstructure of Quenched High-Carbon Steel (Rosenhain), Showing White Needles of Martensite in Darker Austenite

The black needles at the austenite grain boundaries represent some other constituent, perhaps bainite or fine pearlite. Unlike fine pearlite, the martensite needles bear no relation to grain boundaries.

Preventing Hard Cracks

The dependence of the austenite-martensite transformation on temperature is believed by some authorities to account for the valuable effect of preheating to 100–200° C. on the prevention of cracking of low-alloy steels during welding. Hard zones may be formed even with preheat to 100–200° C. but at the preheating temperature so little austenite changes to martensite that cracks do not form. During cooling from the preheating temperature to room temperature, additional martensite forms from the retained austenite. However, the rate of cooling is slow, thermal stresses due to differences in temperature are slight, and it is found by experience that cracking does not occur.

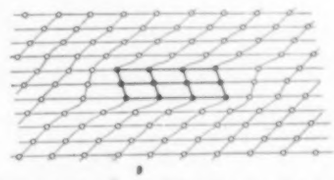

Fig. 54 (*e*)—Schematic Diagram of Precipitation from Solid Solution

The black dots represent atoms of a new crystal, such as Fe_3C, that has formed in the previously uniform crystal of open-circle atoms. Note the distortion of the lattice near the new crystal. The change of austenite to martensite is of a different character about which little is known in the steels we customarily weld.

Now suppose that the preheating temperature, C in Fig. 54, is above the highest temperature at which martensite can form. Obviously, austenite cannot change to martensite no matter what rate of cooling prevails, so long as the preheating temperature is maintained. Nevertheless, any austenite that reaches the vicinity of the preheating temperature may require a long time for complete transformation to products other than martensite. For a steel containing 0.1% C, 5% Cr, ½% Mo or 0.4% C, 1.8% Ni, 0.8% Cr, 0.3% Mo (A. S. T. M. grain size 7–8), for instance, a week may be required for complete transformation of austenite at 500 or 400° C., respectively. For this reason rapid cooling from preheating temperature is not advisable for the higher-carbon and alloy steels. With many steels preheating above the maximum temperature for the austenite to transform to martensite is sufficient to prevent zones of martensite next to the weld, regardless of cooling rates from preheating temperature, provided that the preheating temperature is maintained throughout the period of welding.

Before discussing the effect of preheating on shrinkage stresses, let us consolidate the results of the last three paragraphs. We know that hard zones sometimes occur in the heat-affected zone of welded medium- and high-carbon steels, and we know that if there is a hard zone cracks may occur during the last stages of cooling. It seems logical to deduce that shrinkage stresses, augmented by the expansion when austenite transforms to martensite, cracks the martensitic zone, which is both hard and lacking in ductility. Preheating to a low tem-

perature, 100–200° C., which is adequate for the lower-carbon and low-alloy steels, may either prevent austenite from transforming to martensite by reducing the cooling rate or cause the austenite to change very slowly to martensite, both actions preventing cracks. Preheating to higher temperatures, 300° or 400° C., which is often necessary for steels with over 0.30% C., prevents the formation of martensite during welding.

The products other than martensite to which austenite transforms in preheated welds may be pearlite or the less well known bainite. Heat-affected zones containing pearlite, even the very finest pearlite, will be capable of far more deformation without cracking than zones containing martensite. The properties of bainite are not so well known. All available evidence shows that a given steel exhibiting bainite is more ductile than the same steel in the martensitic condition. We are not stating that martensite tempered by reheating to have the same hardness as bainite will be less ductile than bainite, but that martensite generally has less ductility than bainite in the same steel. It happens that bainite is 5 to 30 Rockwell C units softer than martensite, the bainite formed at higher temperatures being softer but not necessarily more ductile than the bainite formed at temperatures just above the martensite temperature *M*, Fig. 54. It is true that martensite, if reheated to the temperature at which bainite forms on cooling, may become as ductile or more ductile than bainite. For welding purposes, however, it is a question of preheating or not preheating. If martensite forms without preheat there is likelihood of cracks in medium-carbon steels. No amount of reheating will heal the cracks.

Preventing Shrinkage Stresses

Besides preventing hard zones or at least rendering them incapable of causing cracks under some conditions, preheating may be beneficial in reducing or preventing shrinkage stresses. To understand the action of preheat on shrinkage stresses, let us return to the bar analogy, Figs. 24 to 27, that was found to be helpful in Part IV, Vol. II. Instead of maintaining the rigid jaws of the press at room temperature, as we did in Part IV, we shall preheat them as well as the bar, Fig. 55, to three typical preheating temperatures: 100, 300 and 600° C. At all times the jaws of the press will remain the same distance apart, and the bar thus will be heated to 1500° C. and cooled again under complete restraint. During heating the stress in the bar without preheat, Fig. 55 (*a*), rises to the yield stress in compression as in Fig. 27 (*b*), and remains at the yield stress throughout further heating.

We know from Fig. 56, that the yield stress of steel determined in a test lasting a few minutes drops nearly to zero at temperatures above 600° C. Consequently, by the time the bar in Fig. 55 (*a*) has reached 600° C. the stress in it has dropped nearly to zero. The rate at which the bar is heated will determine to some extent the temperature at which the stress becomes zero. Rapid heating has the effect of rapidly straining the steel. At rapid rates of strain the yield stress is higher than at low rates. Since high rates of heating prevail in some processes of welding, such as spot welding, the temperature at which the stress drops nearly to zero in the zone heated above 600° C., during welding may be 700° C. or so. Cooling rates generally are slower than heating rates and we need expect no great effect of rate of cooling on the temperature at which the yield stress rises on cooling, except at slow rates of cooling created by artificially retarding the cooling.

Returning to Fig. 55 (*a*), we observe that the bar is free from stress to all intents and purposes above 600° C. When the bar cools from 1500° C., Fig. 55 (*b*), it reaches the tensile yield stress, which is very low above 600° C. and yields; that is, its diameter is reduced while its length remains unchanged and equal to the length between the fixed jaws. At 600° C. and below the yield stress rises and the shrinkage stress likewise rises. The shrinkage stress is close to the yield stress at all temperatures and unquestionably is at the yield strength when the bar has cooled to room temperature.

The effect of preheating press and bar to 100° C. is illustrated in Figs. 55 (*c*) and (*d*). Events are practically the same as with no preheat; the bar ends the cycle with tensile shrinkage stress up to the yield strength at 100° C. Preheating to 300° C., Figs. 55 (*e*) and (*f*) does not alter the cycles of events on heating and cooling, although the maximum compressive stress on heating and the tensile shrinkage stress on cooling to 300° C. will probably be lower than with 100° C. due to the lower yield stress at 300° C. compared with 100° C.

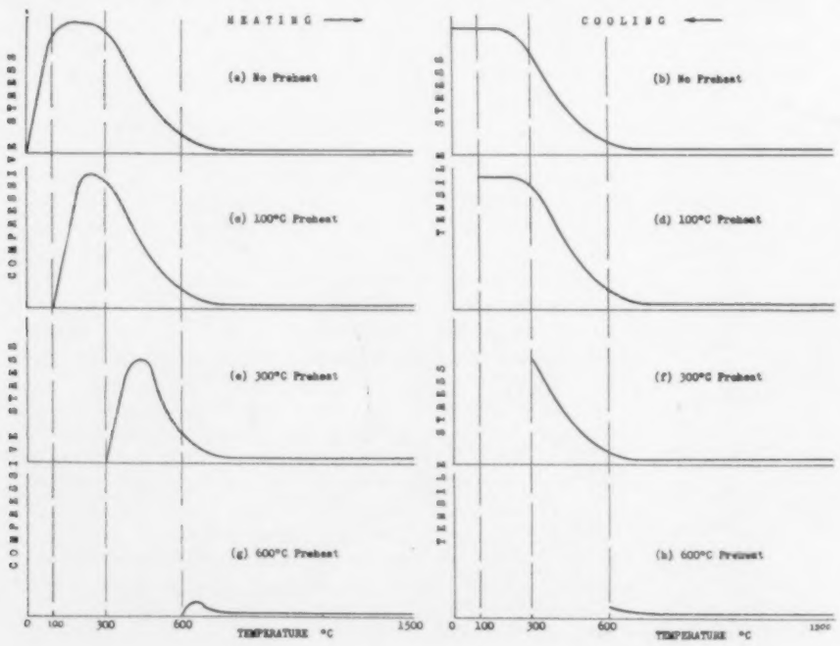

Fig. 55—Stress-Temperature Curves for Bars Under Complete Restraint During Heating and Cooling

The jaws of the restraining press remain at preheat temperature throughout the experiments

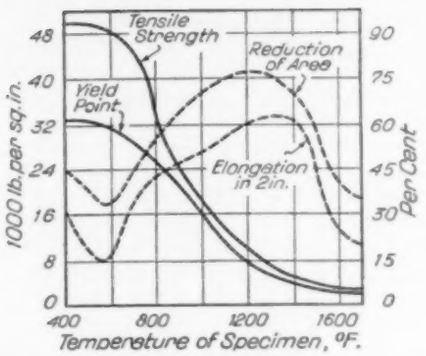

Fig. 56—Short-Time Yield Strength of Wrought Iron at High Temperatures. (Metals Handbook)

When bar and press are preheated to 600° C., the stresses are vanishingly small at all temperatures. The bar was completely restrained during heating from 600 to 1500° C. and therefore was upset. On cooling back to 600° C. the upset was removed completely. Preheating to 600° C., therefore, has prevented shrinkage stresses. But, it may be objected, do not shrinkage stresses appear if the bar is cooled to room temperature? The question reveals a lack of comprehension of preheating, for when we cool a welded part after preheating, not only the welded zone (the bar) is cooled, but the remainder of the part also, corresponding to the press. It is true, therefore, that if we cooled the bar only, tensile shrinkage stresses would appear in it, but when we cool both press and bar uniformly to room temperature, no shrinkage stresses can occur.

It is as if we released the bar from the press and cooled it freely without restraint. The bar would contract an amount exactly equal to the contraction of the distance between the jaws of the press during cooling. The released bar therefore can be fitted exactly between the jaws of the press again after both have cooled to room temperature without applying stress. Had the preheating been local instead of total (torch or induction coil preheat instead of furnace preheat) it is obvious that the cooling of the preheated region to the temperature of the rest of the part would create shrinkage stresses that may be more or less severe than the stresses caused by welding alone depending on circumstances. If shrinkage stresses must be kept at a minimum, any application of local preheat must be studied to avoid them.

In addition to reducing shrinkage stresses, preheating to the higher temperatures, above 300° C., reduces overall distortion (upset) appreciably and reduces the yield strength of the part. Reducing the yield strength of the part relieves shrinkage strain, which, if forced to occur solely in the highly heated zone in the immediate vicinity of the weld, might lead to hot cracks in weld metal or in base metal close to the weld.

Preheat may serve still another purpose. Stainless iron containing 16% Cr should be preheated to prevent shrinkage stresses acting on the coarse-grained weld metal and heat-affected zone at the low temperatures at which they are brittle. Preheating to 100° C. or less may help to serve a similar purpose in preventing cracks in hard zones near welds in medium-carbon steels.

Need we restrict preheating to temperatures below 600° C.? For practical reasons we must, but there are conditions in which we make use of higher preheats perhaps unwittingly. As the preheating temperature is raised, cooling rates become slower, and the region heated to at least above the critical range becomes correspondingly wider, Figs. 57 (*a*) and (*b*). There has been no change in grain size in the regions outside the critical limits. Were the plates preheated above the critical range to start with, there would be no region outside the critical limits, of course. The grain size of the plate as a whole would be refined before welding was begun. Welding therefore, would exert no grain refining effect; its only effect would be to increase the grain size close to the weld (see Fig. 54, Part VIII of Vol. I).

Multi-Layer Welding

These considerations have a bearing on the grain refinement of the preceding weld bead by a succeeding one. In Fig. 57 (*c*) small bead 2 has raised a small part of bead 1 above the critical thus refining the grain size of that region; bead 1 had been allowed to cool to room temperature before bead 2 had been deposited. In Fig. 57 (*d*) bead 2 had been deposited soon after bead 1; in fact, bead 1 was at 500° C. when bead 2 was deposited. As a result, more of bead 1 was heated above the critical than in Fig. 57 (*c*). In Fig. 57 (*f*) bead 2 had been deposited nearly at once after bead 1, which had not cooled below the critical, say 900° C. The grain size of bead 1 therefore was not refined by being reheated above the critical.

We see that the time between beads affects the extent to which the grain size is refined. Depositing beads one immediately after the other may result in no grain refinement of the weld metal. Allowing previous beads to cool to room temperature before depositing the next bead will yield less grain refinement than depositing the next bead while the preceding bead is hot but below the critical. The significance of refining successive weld beads as completely as possible is reflected in notch impact value. Tensile values are little, if any, affected by the degree to which successive beads are refined. High degree of grain refinement always is favorable for high notch impact value of weld metal, particularly at low temperatures.

Comparing bare with covered electrodes on the basis of degree of grain refinement of weld metal, we find that bare electrodes usually deposit at lower arc energies than covered (amp. × volts; arc voltage is usually about 18 for bare, 30–35 for covered); as a result the covered electrode produces a wider heat-affected zone (region heated to at least the critical) than the bare electrodes. Furthermore the slag on covered electrode

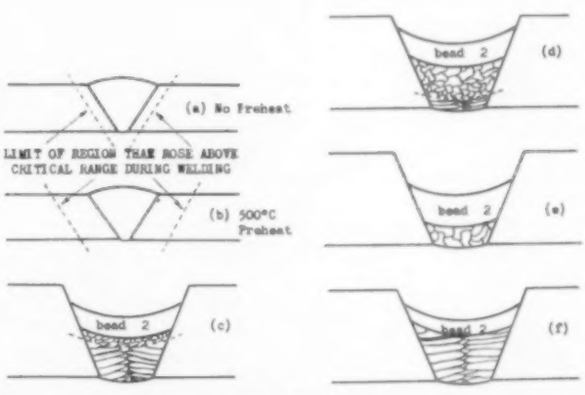

Fig. 57 (*a*) and (*b*)—Heat-Affected Zone Is Widened by Preheating
(*c*)—Bead 1 Cooled to Room Temperature Before Bead 2 Was Deposited. Only a Small Portion of Bead 1 Was Refined by the Heat of Bead 2
(*d*)—Bead 1 Was at 500° C. When Bead 2 Was Deposited. A Large Part of Bead 1 Was Refined by the Heat of Bead 2
(*e*)—After Small Bead 1 Had Cooled Below the Critical, Large Bead 2 Raised It Completely Above the Critical and Refined the Grain
(*f*)—Bead 1 Never Cooled Below the Critical Before Bead 2 Was Deposited

welds reduces their cooling rate so that they are at a higher "preheat" than beads from bare electrodes when the next bead is deposited. In addition the bare electrode metal generally has lower carbon and manganese contents than metal deposited by covered electrodes. The higher criticals associated with the lower C and Mn contents also favor small heat-affected zones in bare electrodes, although the high-nitrogen content of bare electrode metal (0.10–0.15% N_2) offsets the effect somewhat. Whether the difference in inclusion content between the two types of weld metal affects the critical range through the nucleating influence of inclusions is doubtful.

It is a rule that the smaller the initial grain size the smaller is the grain size after reheating above the critical and cooling below it again. Small beads generally exhibit smaller dendrites than large beads, because the dendrites cannot grow so far in the small beads as in the large, and the small bead cools more rapidly, which accentuates the nucleating effect of undercooling below the equilibrium freezing range. Since the small bead has the smaller grains to start with, it will have finer grains after being reheated above the critical than the large bead. Besides, the heat-affected zone created by the second bead will extend to a greater distance through the small bead than through the large bead. However, the small bead cools more rapidly than the large and may not be at so high a "preheat" when the second bead is deposited.

It is often desirable in a multilayer weld to eliminate all coarse grain structure in the heated base metal. After the first six beads in Fig. 58 have been deposited there will be coarse grain structure in base metal only close to beads 5 and 6, assuming that the successive beads have raised the temperature of the coarse zone created by the preceding bead above the critical range. If the size of the last bead and the temperature of the joint as a whole is such that the limit of the zone heated above the critical by bead 7 is *A-A*, the coarse zones from beads 5 and 6 will not be refined, and the joint will not have the highest notch impact value. There will be coarse structure at the notch represented by the toe of the weld. Therefore, the last bead should be deposited at sufficient energy (taking into account "preheat," the time interval between beads 5 and 6 and 7, and the size of bead 7) to spread the critical zone to *B-B*. It is a characteristic of customary weld metal related to its low-carbon content that it is not so likely to become coarse grained; that is, to develop Widmannstätten structure, as customary wrought steel. Therefore, the structure of beads 5 and 6 will not be significantly coarsened by the heavy bead 7 that may be necessary to create the grain refining effect that may be desired.

In oxygen cutting medium-carbon steels, it may be necessary to prevent cracks. Either preheating or postheating is resorted to. Instead of preheating the entire plate it is customary simply to precede the cutting torch by a preheating flame which preheats the line of the cut to the desired extent. The effects of the preheating are identical with those discussed earlier in this section.

When postheating is resorted to, a large, multi-tip torch follows directly behind the cutting torch. The postheating torch does not affect heating rates in front of the cutting torch, which often are inconsequential except for tool steels and similar materials. The postheating torch, however, prevents rapid cooling by maintaining the cut at a high temperature for some time. By increasing the heat input of the operation, postheating reduces the cooling rate and, if adequate, prevents hard zones—martensite. Any other effect of postheating is immaterial. Indeed, there is no essential difference between postheat and preheat, provided postheating is applied before the part has cooled nearly to room temperature, in which event martensite may have formed with accompanying cracks, which postheating is helpless to heal.

Fig. 58

Stress Relief Heat Treatment

According to "Definitions of Welding Terms" of the AMERICAN WELDING SOCIETY, stress relief heat treatment is "the uniform heating of a structure or portion thereof, to a sufficient temperature below the critical range, to relieve the major portion of the residual stresses, followed by uniform cooling." In a footnote to the definition the Committee states that terms such as "annealing" and "normalizing" are not substitutes for the term "stress relief heat treatment." Temperatures for annealing and normalizing are above the critical range, whereas temperatures for stress relief heat treatment are below the critical range. To be sure, shrinkage, or, as they are called, residual stresses due to welding are relieved by annealing and normalizing, but these treatments involve changes in grain structure and particularly dimensional changes that may be injurious to the part. Heat treatment within the critical range always is undesirable. Consequently, stress relief heat treatment is performed below the critical range.

The temperature at which stress relief is performed for welded power boilers and unfired pressure vessels is prescribed by A. S. M. E. Codes for these products.

"Where stress relieving is required it shall be done by heating uniformly to at least 1100° F. and up to 1200° F., or higher, if this can be done without distortion. The structure or parts of the structure shall be brought slowly up to the specified temperature and held at that temperature for a period of time proportioned on the basis of at least one hour per inch of thickness and shall be allowed to cool slowly in a still atmosphere. The structure shall be stress relieved by any of four methods:

"1. Heating the complete vessel as a unit.

"2. Heating a complete section of the vessel containing the parts to be stress relieved before attachment to other sections of the vessel.

"3. If the vessel is stress relieved in sections, stress relieving the final girth joints by heating uniformly a circumferential band having a minimum width of six times the plate thickness on each side of the welded seam in such a manner that the entire band shall be brought up to the temperature and held for the time specified above for stress relieving.

"4. Nozzles or welded attachments for which stress relief is required, may be locally stress relieved by heating a circular area around the nozzle attachment provided any part of the welded edge thereof is not less than 120 times plate thickness from the nearest adjacent welded joint or other element that would restrict the free expansive movement of the heated area."

The temperatures commonly used for stress relief heat treatment are 1100 to 1250° F., which are below the critical range on heating of the plain-carbon and low-alloy steels fabricated by welding. For high-alloy steels,

such as stainless steels, different temperatures are used (see Part VII, Vol. II), while welded Monel Metal (67Ni–33Cu) structures may be stress relieved at 1150° F. The time at temperature in stress relieving plain-carbon steel is customarily 1 hour per inch of thickness, although longer times are required at 1100° F. than at 1250° F. for the same degree of stress relief. Stress relief often is required for preheated parts; with complicated structures or with steels such as ½% Mo, 0.2% C, having a pronounced tendency toward cracking it is essential that the welded part be placed at once in the stress relieving furnace without cooling from preheat temperature.

There are four general effects of stress relief heat treatment:

1. Recovery and relaxation (release of shrinkage stresses).
2. Tempering or drawing (removal of hard zones)
3. Recrystallization.
4. Spheroidizing.

The first effect is universal; the second effect is exerted only if hard zones have formed as a result of welding and the last two effects have minor significance for welding. Under some circumstances stress relieving may have additional effects.

Our welded structures have shrinkage stresses near the yield strength whether there was external restraint or not during welding (see Part IV, Vol. II). We wish to reduce or relieve them to low values, as close to zero as possible. Unless the shrinkage stresses are reduced nearly to zero, the part is subject to brittle failure owing to tensile shrinkage stresses and tensile service stresses acting in two or three directions at right angles. Under multi-axial tensile stress, particularly shock, we know that metal can deform little under stress and fractures in a brittle manner at very small deformations. In addition, if the welded structure, for example an engine base, is machined before stress relief heat treatment, the machining operation removes metal under shrinkage stress, thus creating re-distribution of stress and causing distortion. The machinist cannot be certain that he is machining to the correct dimensions unless the part has been stress relieved beforehand.

Besides having shrinkage stresses, the welded part may have undergone a little permanent deformation not only at high temperatures but at low temperatures as well, Fig. 27 (*d*). Permanent deformation below 850 or 1000° F. is accompanied by slip lines in the microstructure. The slip planes represent planes in the grains of steel which have moved over each other (see Part V of Vol. I). Slip due to permanent deformation at higher temperatures occurs in the same way but the slipped

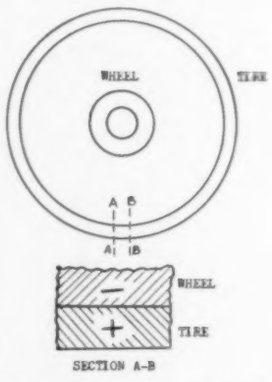

Fig. 59—Shrinkage Stresses in a Shrunk-On Tire
Compressive stress in the wheel, tensile in the tire

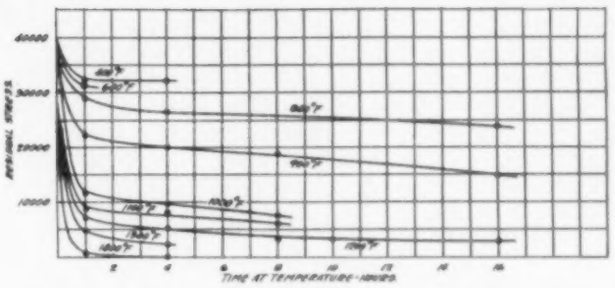

Fig. 60—Influence of Temperature and Time on Relieving Stress in Boiler Steel Through Elongating Beyond the Yield Point at Room Temperature

The steel contained 0.21% C, 1.44% Mn and its mechanical properties were: proportional limit = 34,900 lb./in.², tensile strength = 70,000 lb./in.², elongation = 36.5%, reduction of area = 73%. The internal stress is relieved rapidly at 1400° F., slowly at 400° F. (Hiemke). Hiemke states, "The internal stresses are reduced by permanent yielding, caused first by the reduction of yield point at elevated temperature, and second by creep under prolonged loading at elevated temperature."

planes instantaneously straighten out and lose all trace of the curvature involved in slip.

The welded structure that we are about to stress relieve thus contains shrinkage stresses, tensile and compressive, of all magnitudes up to the yield strength, and also has some cold-worked crystals with slip lines. Our welded structure is in a condition similar to the wheel with shrunk-on tire in Fig. 59, which, in turn, resembles a girth weld joining a head to a drum. The tangential shrinkage stresses are tensile at the circumference, compressive toward the center. Hard zones we shall assume to be absent for the moment.

Recovery

We now raise the temperature uniformly—uniformly in order to keep all parts of the structure as nearly as possible at the same temperature at all times to prevent thermal stresses, Fig. 27 (*a*). As the temperature is raised through the first 200° C. or so, there is no observable change in grain structure, yet the shrinkage stresses decrease a little. The decrease is due to a phenomenon called recovery. It is a general rule that internal stresses in a material decrease when the temperature is raised. In many metals, such as tin and lead, internal stresses decrease nearly to zero at room temperature, and there is evidence that shrinkage stresses in steel may decrease slightly at room temperature. The decrease in steel at 400° F. is shown in Fig. 60, and cannot be due to a decrease in yield strength for it is higher in steel at 400° F. than at room temperature. Recovery also causes changes in electrical and magnetic properties, suggesting that its effect on internal stresses is related to some obscure movements among the electrons and atoms of the steel as its temperature is raised.

However, the release of shrinkage stresses at the lower temperatures is not adequate and the temperature must be raised still higher. At all temperatures an increase in time at temperatures reduces the stress still farther, but the major release of shrinkage stresses occurs during the first hour.

Relaxation

Upon raising the temperature to 1000° F. or higher we find that relaxation occurs and shrinkage stresses are relieved swiftly and completely, Fig. 60. The change during relaxation is shown in Fig. 61. A bar of steel is stretched to the yield stress in tension at room temperature, Fig. 61 (*a*) upon welding it into a frame. The atoms stretch apart perpendicular to the load and move close together parallel to the stress, which indeed is the basic meaning of stress—a movement of the atoms to positions capable of withstanding load. At 1000° F. the short time yield strength is only a fraction of the yield

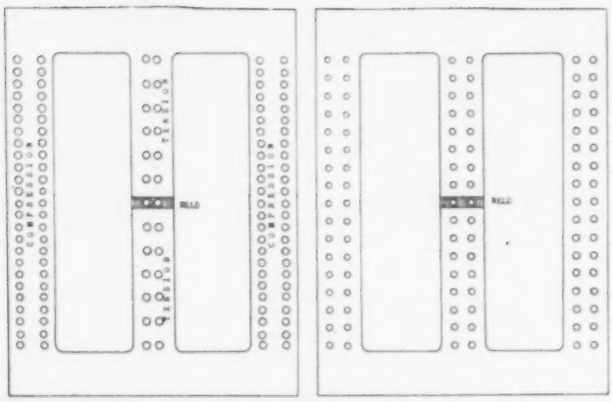

Fig. 61 (*a*) and (*b*)—Stress-Relief Heat Treatment Removes Shrinkage Stresses by Permitting the Atoms (Open Circles) to Creep Back to Equidistant Positions

In (*a*) "as-welded," the atoms in the outer arms are compressed together vertically, the atoms in the inside arm are drawn apart vertically. That is, the outer arms are in compression, the inner arms in tension due to welding. After stress-relief heat treatment (*b*) at 1000° F. the atoms are neither pressed together nor drawn apart in any of the three arms. The shrinkage stresses have been "relieved"

strength at room temperature. That is to say, the atoms no longer can withstand the stress, and return closer and closer to the equidistant positions occupied by atoms in a crystal under no stress. The center bar shortens, the outer bar lengthens. The dimensional changes are slight and the distortions are magnified greatly in Fig. 61 (*b*).

The stress decreases until the atoms no longer yield. While the atoms of steel can withstand stress up to the yield value indefinitely at room temperature, at 1000° F. the atoms may be able to withstand considerable stress without yielding if the stress is applied and the temperature is maintained for only a short time. Increasing the time, however, causes yield. More precisely stated, the atoms move continuously under all stresses. The motion is so slow and minute at room temperature as to be undetectable after hundreds of years, Fig. 61 (*c*), but at 1000° F. the motion of the atoms is not necessarily of the type we have considered, but may involve obscure motions at the grain boundaries. Both types of motions constitute flow or creep of the metal.

Relaxation, therefore, is a form of creep. The distortions created by relaxation or stress relief in a welded structure are difficult to compute, but generally are far smaller than the distortions created by machining unstress relieved parts, because in machining we generally remove the most highly stressed material.

How can we favor stress relief? Resistance to relaxation or creep should be low. Fig. 60 shows that the most effective method of favoring stress relief is to raise the temperature. The extent to which the temperature may be raised is governed by permissible distortion due to unsupported mass. Furthermore, it is never advisable to raise the temperature into the critical range. Increase in time also favors stress relief. It is a general rule that coarse McQuaid-Ehn grain size improves resistance to creep above 800° F., but the improvement exerts no detectable influence on stress relief at 1100° or 1200° F. The higher the initial shrinkage stress, the higher is the stress after stress relief at a given temperature for a given time, owing to the progressive strengthening involved in the greater release of strain. The release of strain may be looked upon as cold work during stress relief, which naturally strengthens the crystals. Since nearly all types of welds in a given steel have maximum shrinkage stresses near the yield strength, no deduction in time of stress relief can be made solely on the basis of apparent absence of restraint during welding.

Structures that are made of steels designed to have exceptional resistance to creep at elevated temperatures will relax less rapidly than mild steel. The creep-resistant steels, for example ½% Mo, 0.2% C, require higher temperature or longer time at temperature for a given degree of stress relief than unalloyed steel.

A second bead relieves the shrinkage stresses in the underlying bead, but creates new shrinkage stresses. Consequently, multi-pass welds have no lower shrinkage stresses than single-pass welds and require stress relief to the same extent. Besides becoming more complicated as the thickness is increased, shrinkage stresses in thicker parts require longer time for relief than in thinner parts because the surface of the part is the first to reach the temperature of the furnace. More time elapses before the center of the thick sections reaches furnace temperature than the center of thin sections.

Recrystallization

Cold work or permanent deformation below the recrystallization range breaks each perfect crystal grain into a large number of fragments due to slip. These fragments change into new grains with undistorted crystal lattices when the temperature is raised to the recrystallization range. The appearance of the new grain among the old grains containing slip lines is known as recrystallization (see Part IV of Vol. I). The new grains appear first as minute crystals usually at the grain boundaries of the cold-worked grains—recrystallization has begun. As the temperature is maintained or increased, the minute crystals grow. Eventually all the old crystals with slip lines have been absorbed by the new crystals, which are free from slip lines, and recrystallization is complete.

Recrystallization transforms the distorted fragments, which are the source of internal stresses, to new, undistorted crystals free from internal stress. Recovery, Fig. 62, partly removes shrinkage stresses, recrystallization completes their removal. The temperature at which recrystallization occurs in a given metal is lowered by increasing the time at temperature, and by increasing the degree of prior cold work. There is no single recrystallization temperature for a given metal. For iron and steel the lowest temperature at which recrystallization has been observed is 840° F.

However, no recrystallization whatever occurs if there is inadequate cold work. The cold work caused by the shrinkage of parts during cooling after welding generally is too slight to cause recrystallization during stress-relief heat treatment. Stress relief occurs, therefore, through recovery and particularly relaxation, rather than through recrystallization.

Tempering or Drawing

Raising the temperature of quenched steel to any temperature below the critical range is called tempering

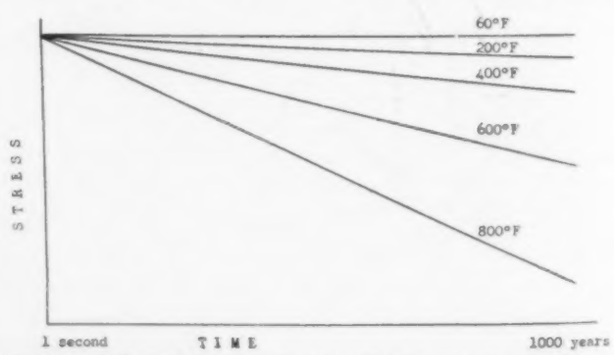

Fig. 61 (*c*)—Schematic Diagram (Log-Log Plot) Showing the Decrease in Shrinkage Stress with Time at Different Temperatures (Relaxation) Assuming No External Load

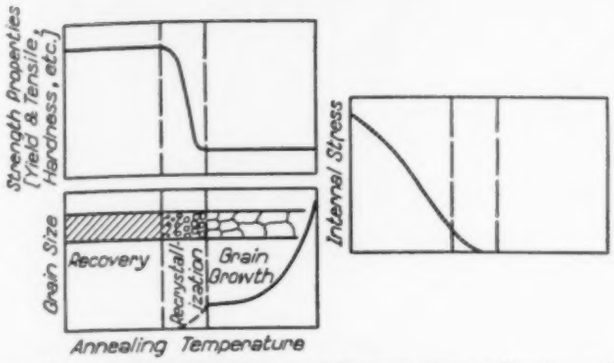

Fig. 62—Schematic Representation of Recovery, Recrystallization and Grain Growth. (Mehl and Sachs)

or drawing. The heat-affected zone close to welds made without preheat or with insufficient preheat in medium-carbon and many other high-tensile steels cools so rapidly as to be quenched. While the quenched zone was above its critical range during welding, it consisted of austenite containing ten times as much carbon in solid solution as is soluble at room temperature. During quenching the austenite changes largely to martensite: a crystalline form of steel intermediate between face-centered and body-centered. The carbon in martensite probably exists as tiny crystals of iron carbide (or carbides containing alloying elements in alloy steels), which are believed to account for the great hardness of martensite compared with any other state of a steel.

When the temperature is raised, the zone containing martensite undergoes three changes:

1. Martensite changes to ferrite (body-centered cubic crystals).
2. Any austenite that had not changed to martensite during quenching changes to ferrite and carbide.
3. The minute crystals of carbides in the martensite and the larger crystals of carbide in other constituents, such as fine pearlite, increase in size.

The temperatures at which changes 1 and 2 occur are not known precisely. In plain-carbon steels with about 0.7% C change 1 occurs at 300° F., change 2 at 450° F. Appreciable amounts of austenite are retained on quenching plain-carbon steels only if the carbon content is 0.4% or more. Austenite is retained with lower carbon contents if alloying elements are present. The growth in size of carbide particles is continuous as the temperature is raised. Change 3 seems to account for the major drop in hardness on tempering. That is, the hardness of martensitic steel depends on a fine dispersion of carbide particles on each crystal plane, which hinder slip and thus raise hardness while reducing ductility. Reheating coarsens the carbide particles and reduces their number, thus reducing the hardness.

The hardness after tempering or drawing depends primarily on the tempering temperature. Time at temperature also is important, Fig. 63. After 1 minute at 1200° F. the hardness at room temperature drops from 56 to 27 Rockwell C for the quenched 0.35% C steel. After an hour the hardness has dropped to 18 C. The reduction in hardness caused by stress-relief heat treatment of a welded medium-carbon steel containing hard zones depends largely on the time of treatment. The greatest reduction in hardness as well as in shrinkage stresses occurs in the first few minutes. For maximum effectiveness, prolonging the treatment is essential. The hardness after the first few seconds at 1200° F. is nearly the same whether the steel consisted initially of martensite, bainite or fine pearlite.

Concurrent with the softening during tempering there is a rise in ductility as revealed in the static tensile test and a decrease in tensile strength. Notch impact values and other measures of toughness, however, often are minimum after tempering at 400–700° F. rising to high values above 800° F. The reduction in notch toughness is attributed to internal stresses created by the expansion of retained austenite during its decomposition. Welded parts containing hard zones should not be heat treated at 400–700° F. The softening of plain-carbon steel is continuous as the tempering temperature is raised, because the main process is the agglomeration and growth of carbide particles. When carbide-forming alloying elements are added to steel, the steel may become harder instead of softer as the tempering temperature is raised in some ranges, Fig. 64. The 5% Cr–½% Mo steel with 0.35% C is harder after tempering at 900° F. than after tempering at 700° F. The increase is called secondary hardness and is due to the formation of minute crystals of a second compound after the iron carbide has coalesced to a degree no longer very effective as a hardener, as Bain discovered. The minute crystals of alloy carbide form at elevated temperatures which provide the necessary opportunity for diffusion. Secondary hardness extends its influence through the alloying elements to the temperatures of stress relief heat treatment, as Fig. 64 shows. It is to their hardness as well as their creep resistance that is due the extra precautions in stress relieving some of the high-alloy steels.

Tempering is important not only in stress relief heat treatment of welded parts containing hard zones, but in multi-layer welding of medium-carbon and other strongly hardening steels as well. In Fig. 65 (*a*) bead 1 has created a hard zone. Bead 2 likewise has created a hard zone by raising the temperature of base metal close to the weld above the critical range and allowing it to cool rapidly. If the heat in bead 2 is sufficient to raise the entire hard zone of bead 1 above 500° F. (but not above

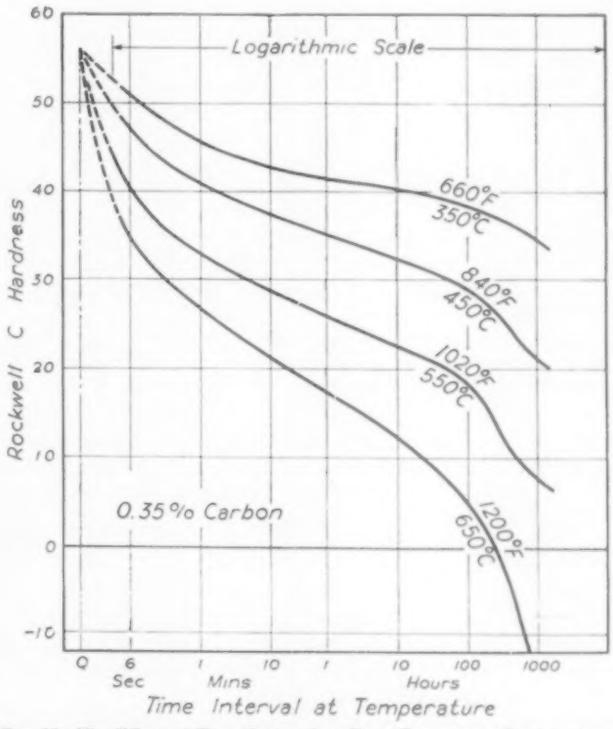

Fig. 63—The Effect of Time Interval at Four Tempering Temperatures on the Softening of Quenched 0.35% Carbon Steel. (Bain)

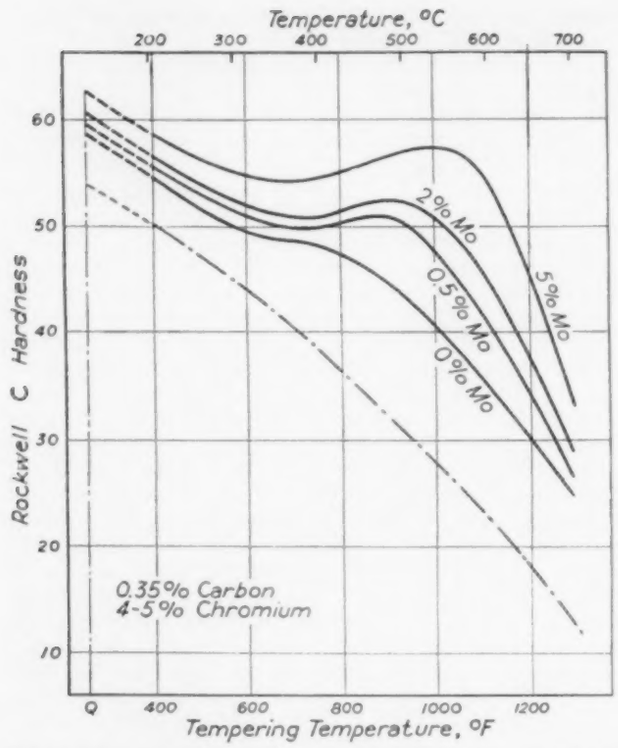

Fig. 64—The Softening, with Increasing Temperature, of 4.0-5.0% Chromium, 0.35% Carbon Steels with Increasing Molybdenum Contents. (Bain)

— · — · — · — · — · — · — 0.35% carbon steel without chromium or molybdenum

the critical range, of course), the zone will be considerably softened and will be devoid of martensite and austenite. Whether its notch impact value will be raised necessarily is problematical. In general, however, it may be said that the tempered hard zone will be considerably tougher than the untempered zone. If bead 2 had been deposited directly after bead 1, it is possible that bead 1's hard zone would have been caught before it had formed, so to say. That is, the zone that would have become hard on further cooling, would have been prevented from further cooling by the second bead before martensite had begun to form. The hard zone might then have consisted of bainite or fine pearlite instead of martensite, depending on the precise temperature distributions prevailing. Furthermore, the heat from bead 1 might have retarded the cooling rates in bead 2 and so have prevented hard zones near it. Hard zones, it will be realized, are within the control of the operator to some extent, although he cannot change the composition of the base metal.

In Fig. 65 (*b*) bead 2 has been deposited after bead 1 has cooled and is too small to bring the entire hard zone of bead 1 above say 200–300° F. Significant tempering has failed to occur and the hard zone is there to stay for it is too much to expect that later beads can succeed where the second has failed. With proper welding, however, it is possible to temper the hard zones of every bead in a multi-layer weld, Fig. 65 (*c*).

Spheroidizing

Spheroidizing is the process of creating carbides having the shape of spheres in the steel. If we start with pearlite, we spheroidize by converting the plates of carbides to spheres. If we start with martensite or bainite, on the other hand, in which the minute carbides are approximately spherical initially (although on account of their extreme fineness we cannot be certain of their presence, let alone their size), spheroidizing consists simply of coalescing the particles and rendering them visible under the microscope. Martensite needles do not spheroidize.

The carbide in the heat-affected zone of welded low-carbon steel usually is present as pearlite. During stress relief heat treatment we observe that the plates become less and less angular, the carbide particles becoming more nearly spherical, Fig. 66 (*a*) and (*b*). The longer the time at temperature and the higher the temperature, provided the critical range is not exceeded, the larger and more nearly spherical the carbides become. Carbon appears to dissolve at the edges of a plate of carbide to be precipitated again toward its middle.

The carbide in the hard heat-affected zone of welded medium-carbon steel is extremely finely divided, Fig. 66 (*c*). As the temperature rises during stress relief heat treatment, the carbides follow the general law of small particles in a metal. Carbon from the smaller particles enters solution to precipitate again on the larger. In this way a few large spheroidal carbide particles replace a crowd of tiny spheroidal ones. Since the coarsely spheroidized condition generally is the softest and most ductile, the spheroidizing action of stress relief heat treatment is desirable.

When the welded part is at 1200° F., steel has appreciable solubility for several elements, particularly nitrogen. If the part is slowly cooled from the stress-relieving temperature there is opportunity for complete precipitation of these elements. With rapid cooling, on the other hand, nitrogen is retained in supersaturated solution at room temperature and the steel may have low ductility. Weld metal with high-nitrogen content, such as bare electrode deposits, is particularly subject to embrittlement on rapid cooling from the temperature of stress relief heat treatment. Rapid cooling after stress relieving is undesirable in any event to avoid shrinkage stresses due to the non-unfform distribution of temperature in any rapidly cooled object.

The spheroidizing of the carbide near a welded joint is a process that begins while the weld is being made, Fig. 67. The pearlite in the zone that is heated short of the critical range is more or less spheroidized depending on the length of time it has remained close to the lower temperature of the critical range. Once the pearlite is heated into the critical range the carbide in the pearlite dissolves in the austenite. In very rapid welding processes, such as spot welding, the carbide may not remain in the critical range sufficiently long to dissolve completely in the austenite. Some spheroids may be ob-

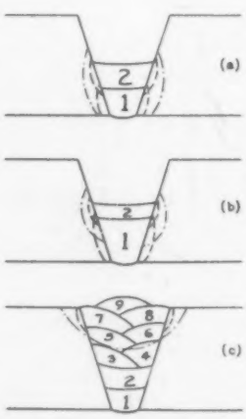

Fig. 65—Tempering of Hard Zones by Heat from a Later Bead

- - - - - - - - - - - - - boundary of hard zone
— · — · — · — · — · — · — boundary of zone heated to at least 500° F. during welding

served, therefore, even in the zone that has been heated into the critical range. During stress relief heat treatment the spheroidization begun during welding is extended to the steel throughout the welded part. All pearlite being spheroidized to some extent by stress relief heat treatment, the outline of the heat-affected zone in the macrostructure of a stress-relieved weld is far less sharp than in the macrostructure before heat treatment. Unlike preheating, however, stress relief heat treatment has no effect on the width of the heat-affected zone.

Although local stress relief has the same effect in softening hard zones as placing the entire structure in the furnace, it may not always reduce shrinkage stresses. Local stress relief is commonly used for high-pressure piping. Raising the temperature of the joint to 1200° C. replaces the non-uniformly distributed shrinkage stresses in the immediate vicinity of the weld by more uniformly distributed reaction stresses. It is important that the deformation necessitated during cooling by the wide heat-treated zone be absorbed without causing cracks or endangering supports. In most structures the severe shrinkage strains involved in local stress relief preclude its use. Instead of relieving stresses, the cycle of local heating and cooling often intensifies them. Local stress relief or local heat treatment of any kind is disastrous for austenitic steels of the 18–8 type because there is always a zone near the locally heated area that enters the temperature range for dangerous carbide precipitation.

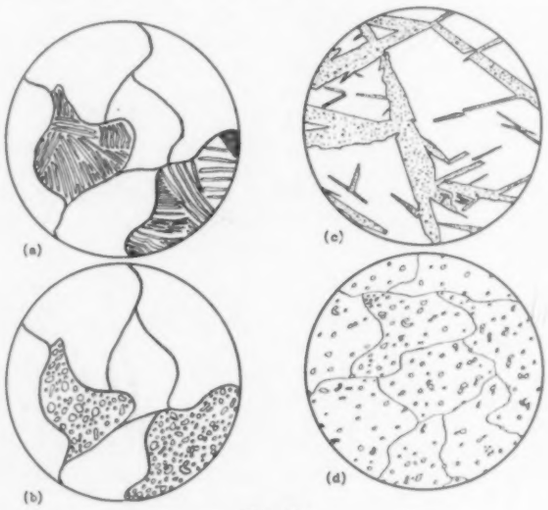

Fig. 66

(a) Pearlitic low-carbon steel before stress relief heat treatment
(b) During stress relief heat treatment of the structure in (a) the plates of cementite tend to spheroidize
(c) Needles of martensite in austenite, showing hypothetical spheroids of carbide in the needles
(d) During stress relief heat treatment of the structure in (c) spheroidal carbide particles tend to grow
In these drawings the degree o spheroidization is exaggerated. The usual stress relief heat treatment does little more than round off the corners of the cementite plates

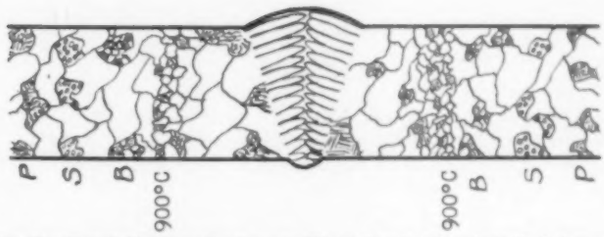

Fig. 67—Sketch Showing the Zone in Which Pearlite Tends to Be Spheroidized in the Welding of Mild Steel

B = Structure of zone heated above the lower critical but below the upper critical during welding (see Fig. 61 of Vol. I)
S = Structure of zone heated just below the critical range during welding. The cementite in the pearlite has spheroidized
P = Structure of zone heated to a maximum temperature during welding that was 100° or more below the lower critical. No spheroidizing has occurred, and the structure is identical with unwelded base metal, namely: ferrite plus pearlite

Annealing and normalizing seldom are applied to welded parts. The high temperatures involved by these heat treatments would cause excessive distortion in almost any welded part despite extensive systems of support in the furnace. An exception is the local annealing of welded rail joints. The annealing of welds in high-carbon steels, such as rails, should be so conducted that there is little or no decrease in carbon content at the surface, called decarburization. The carbon is removed from the surface by free oxygen, carbon dioxide, or steam in the heat-treating atmosphere, and is guarded against by maintaining low free oxygen content by suitable adjustments. Decarburization is inappreciable at the temperatures of stress relief heat treatment.

Questions

1. How does preheating (*a*) retard cooling rates? (*b*) prevent cracks? (*c*) affect the fluidity of weld metal? (*d*) deepen the heat-affected zone?
2. Why cannot local preheating always be substituted for total preheating?
3. Describe the structure of the heat-affected zone of mild steel and of 18–8 after stress relief heat treatment.
4. Assuming that all three arms of the frame in Fig. 61(*a*) and (*b*) have the same cross-sectional area, draw stress—temperature and deformation—temperature charts for both compression and tension arms: (*a*) without preheat, (*b*) with local preheat to 600° C., and (*c*) with total preheat. Will dry ice applied to the compression arms tend to render preheat unnecessary?
5. What occurs during recovery? during recrystallization?
6. Why does local stress relief sometimes widen the zone subjected to high shrinkage stresses?
7. Does stress relief heat treatment make preheating unnecessary? Explain.

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(*Continued on page 612*)

Some Notes on the Practical Application of Seam Welding

By E. A. Mallett*

BEFORE entering into any discussion regarding the various types of seam welding, its application, requirements, etc., it is first necessary that a clear understanding is had of just what is meant by the term "Seam Welding" as used in the resistance welding field. The official definition adopted by the Resistance Welder Manufacturers' Association, the A. I. E. E., and approved as American Standard by the American Standards Association in 1933, reads, "A resistance welding process wherein the weld is made lineally between two contact rollers or a contact roller and a contact bar." However, in general, a weld is not considered a true resistance seam weld unless the pieces to be welded are lapped. Therefore, except where otherwise specified, all the subject matter of this article pertains only to welds wherein the two sheets are lapped. Furthermore, unless otherwise stated, all the subject matter applies only to mild steel, such as automobile stock.

Continuous Seam Without an Interrupter

The simplest form of seam weld is made by passing current directly through the lapped edges of the sheet while running the sheet between the wheels. This process is very successful on relatively thin gages of mild steel. It is found economically practical to use this process on gages up to 18 gage, when 60-cycle alternating current is used. With 28 gage, speeds as high as 40 ft. per minute are quite practical from the point of view of quality of weld, and with 18 gage, speeds of 20 ft. per minute are satisfactory. The weld obtained consists of a series of overlapping spots, each spot of one-half cycle of the line frequency.

On the standard seam-welding machines, difficulty is encountered in going beyond 18 gage, since, when enough current is used to properly weld the material, excessive surface temperature and wheel pick-up cause an unsatisfactory surface. This difficulty can probably be overcome by using larger diameter wheels with wider surfaces and higher welding pressures; these factors continually increase as the gage of the sheet increases. For a majority of production operations, however, this is impractical since the parts being handled are relatively small and cannot be handled at the higher speeds and on the larger equipment.

Continuous Seam Welding with an Interrupter

It has been found that the difficulty can be overcome by systematically interrupting the current, thereby making what is substantially a row of overlapping spot welds, each spot of which may be a number of cycles in length. This immediately permits running at lower speeds with heavy gage material. For example, on a standard seam welder used for fabricating metal parts, 8 gage mild steel may be readily welded at 3 ft. per minute. The common means used for turning the current on and off are electronic seam-welding controls.

Mash Seam Welding

Where it is desired to obtain a weld in which the thickness through the weld is a minimum, this is accomplished by lapping the sheets very slightly and holding them firmly by means of external clamps or their equivalent and welding between two broad faced wheels. This forges the edges together, resulting in a weld which is approximately 25% greater in thickness than the original sheet. The process is carried out without the use of an interrupter, and is not considered practical for application to sheets heavier than 14 gage.

Intermittent Seam Welding

For many practical applications it is not necessary that the seam be water or gas tight. In this case it may consist of a series of spot welds with a gap between them. When these welds are made on a seam welder by running the sheet between the wheels, the process is generally referred to as intermittent seam welding.

General Conditions Necessary for Good Welding

In order to obtain satisfactory seam welds, there are several important factors regarding the condition of the material and the geometry of the parts to be welded which must receive careful attention. As far as surface condition is concerned, clean surfaces are a vital necessity. Cold-rolled steel, hot-rolled pickled or surfaces which have been shot blasted, are very satisfactory and permit extremely clean and uniform welds. Hot-rolled steel with the mill scale in place is decidedly unsatisfactory and such material cannot be successfully seam welded. Any form of rust or surface oxides also prevent successful seam welding. Oils used to prevent rusting on stored sheets are not harmful and have no effect whatever. Some types of protective coatings do not seriously interfere but each one should be considered as a special case and carefully investigated before being used. Coated finish such as galvanized and terne plate are entirely satisfactory for seam welding, details of which will be discussed further on.

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As far as geometry is concerned, the main consideration is that the parts be well formed and fitted before being put in the welding machine. The welder is, as the name implies, a machine for joining the metals. It is not a forging or cold-forming machine and it should not be expected to perform the joint function of forming and welding simultaneously. Where flanges are to be joined, they should be at least $^3/_{16}$ in. in width, or six times the gage thickness, whichever is greater. Where longitudinal seams on cylindrical members are to be made, it is well to spot tack the edges together before seam welding. In special cases of high production equipment, the seam welder may be equipped with special holding fixtures.

Selection of Proper Type of Welding for Various Applications

There are, of course, many factors which enter into the determination of the proper type of weld to be used on any given product. The first thing to be considered is whether a gas or liquid-tight job is required. If not, we can immediately conclude that either continuous, with or without an interrupter, or intermittent seam welding will be satisfactory. If it must be gas tight, intermittent welding cannot be used. The next factors to be considered are the production requirements and the welding speed at which the part can be readily handled. These two factors are, of course, closely related since with high production requirements, parts would be handled automatically, therefore permitting higher speeds than if the operator were called upon to guide the parts through the machine by hand. Having determined the maximum practical welding speed from point of view of handling, this factor and the gage will then determine whether or not an interrupted control is necessary. Limitations in available power system may also make it necessary to reduce the speed.

Type of Machine to Be Used

There are many different types of special seam-welding machines available. There are three standard classifications referred to by their relative size, as light, medium and heavy. Light machines are rated from 50 to 75 kva. with maximum pressure of 1000 lb. and maximum wheel diameter 7 in. Medium machines are rated from 100 to 200 kva. and have a maximum pressure of 2250 lb. and wheel diameter 8 in. Heavy seam welders are rated from 250 to 400 kva, maximum pressure 3800 lb. and maximum wheel diameter 10 in.

In any one of the three sizes of machines there are three general types, one of which is known as the circular seam welder, in which the plane of the wheels is parallel to the face of the machine. The next type is the longitudinal seam welder where the plane of the wheels is perpendicular to the face of the machine. The third type is the universal machine in which the head is constructed in such a manner that it may be rotated. Also, the lower arms are mounted in sockets to permit changing from circular to longitudinal position, and vice versa.

There are two types of drive systems for the welding wheels, the simpler form being the gear drive in which case either the lower or the upper wheel may be driven, the remaining wheel idling. The other type of drive generally referred to as friction drive consists of a steel driving roll running against the surface of the welding wheel itself. With this type of drive either the upper, the lower or both wheels may be driven. Wherever possible, the double friction drive should be used, since by driving both wheels from their periphery, uniform surface speed of the welding wheels is insured regardless of their diameter, thereby eliminating any possibility of slippage between the wheels and the sheet being welded, which would cause a non-uniform weld. In addition to driving, the steel rolls also maintain a uniform surface on the welding wheel, thereby eliminating the necessity for frequent dressing.

This gives a general idea of the types of machines available. It is impossible to discuss here, however, the relative merits of all the various types of machines. Each application should be considered on its own merits.

General Requirements for a Good Welding Machine

Regardless of the particular type of machine which is selected, there are several design features which are essential for good seam-welding results. These features are incorporated into the design of all seam welders of reputable manufacture. They are pointed out here merely as a matter of information.

1. The upper head or moving system should be guided in accurately machined ways (either a quill or slide) of sufficient length to prevent binding under the welding pressure.
2. The moving system should be designed to be as light as possible without sacrificing strength, rigidity or current-carrying capacity of the bearing. Unnecessary weight is considered poor design.
3. Means should be provided to adjust the upper position of the welding head so that a small operating stroke may be maintained as the wheels lessen in diameter due to wear.
4. Bearings should be made of proper materials and with sufficient surface contact to carry the welding current without seizing and without excessive heating.
5. The current-carrying parts should be of proper design to carry the welding current without overheating. It is well to note here that the section of copper is not the determining factor. Adequate water cooling is very essential. A small total section of copper properly distributed and with adequate water pockets will carry a much heavier current than many times the cross section of copper without proper water cooling.

Any welding machine providing the above fundamental features and having the proper geometry to handle the work in mind, and also, of course, having the necessary electrical requirements in the way of available welding current, will make good quality seam welds.

Electrical Requirements

All the discussion up to this point has referred primarily to the mechanical considerations of seam welding. The electrical requirement is rather an involved subject since the actual current for welding depends on numerous variables such as speed, type and gage of material, spots per inch, pressure, and when interrupter is used, relative on and off time, wheel diameter and wheel width. In order to obtain sufficient fundamental data to intelligently determine what welding schedule to use under given conditions to obtain first-class welds and thereby be able to select a machine with proper electrical characteristics, considerable experimental work has been carried out, the results of which are given here.

The available equipment imposed some limitations, others were arbitrarily imposed as being practical limits.

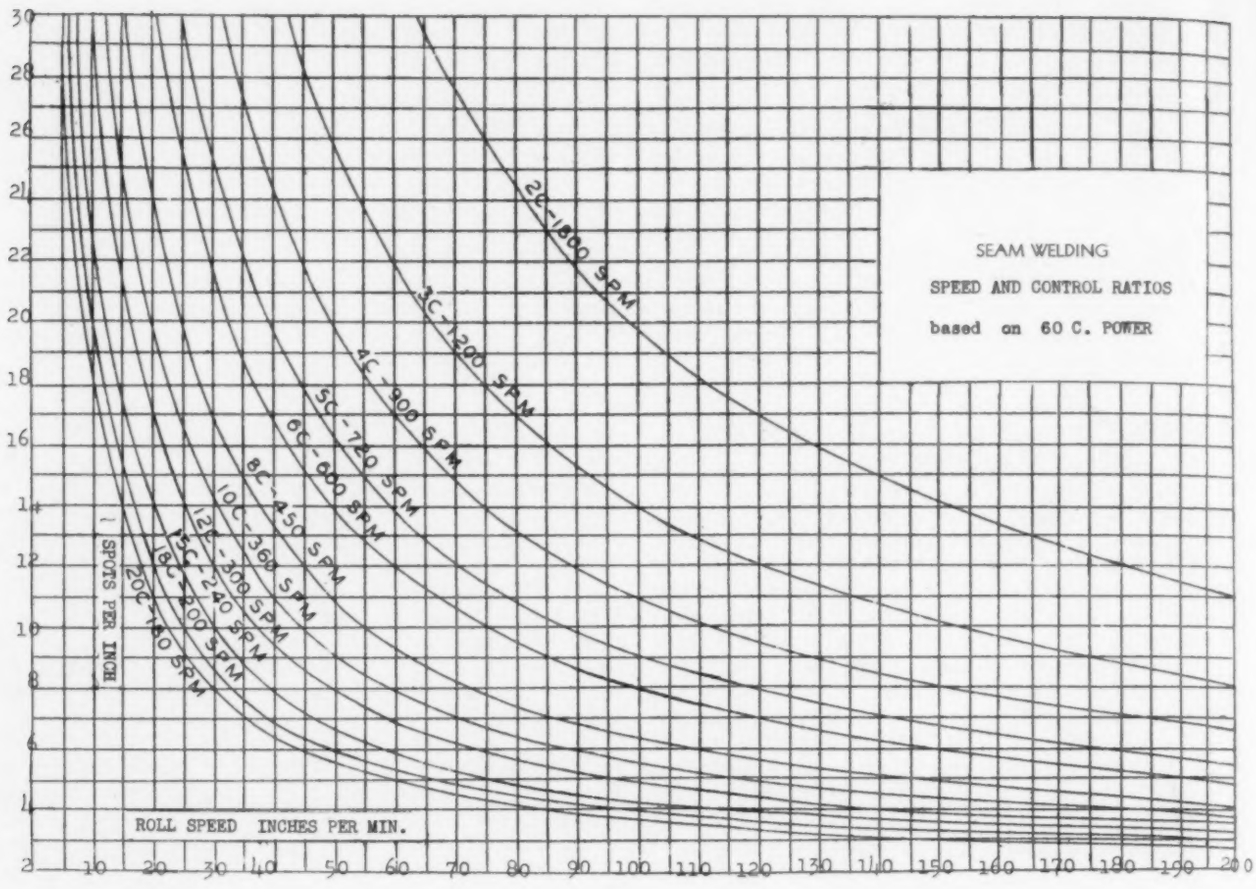

Fig. 1

The following brief discussion of the variables involved will lead toward a better understanding of the tabulated data.

Material.—In all cases two pieces of clean annealed pickled sheet stock free from rust, scale, dirt or grease were used. Welds were made in the middle of strips about 2 in. wide and 12 in. long. This avoided the possibility of a heat unbalance due to welding near the edge of a strip. It also results in all welding current being on the conservative side as it usually takes a little less current to weld at the edge of a plate than at an appreciable distance from the edge due to the fact that there is not as much heat conducted away from the weld by adjacent material.

The strips were of commercial flatness and required no deforming by welding pressure in order to bring them into intimate contact.

Spots per Inch of Weld.—Inspection of the tabulated data indicates that spots per inch are limited to an approximate range of 8 to 12 with the fewer of spots per inch for the heavier gages and the greater number of spots for the lighter gages. Data taken using no interruptions will vary somewhat in spots per inch from the above figures. These values were selected because experience has indicated that for the average application this range of spots per inch will produce a gastight weld if other variables are properly adjusted. The exact selection of the spots per inch used within the above range depends upon the speed of welding, frequency of power supply and timing schedules available from the timing equipment.

Welding Speeds.—These results cover only speeds ranging from 2 to 12 ft. per minute for interrupted welding. Higher speeds are used for continuous seams without an interrupter. It is not meant to imply that either higher or lower speeds cannot be obtained in a practical manner, but that the above range covers the most commonly met applications.

In the majority of commercial applications it is the difficulty of manually operating the machine and guiding the work which limits the speed.

If we assume no timer is used on a power supply of 60-cycle frequency, the maximum speed which can be used to obtain 10 spots per inch is 60 ft. per minute. This is rather high for small parts although a number of installations weld tin can stock in the range of 0.015 in. thickness at a speed of 30 ft. per minute.

Speeds jump by a ratio of 4 to 1 when the use of interruptions is eliminated. For example, compare 10 spots per inch with a time schedule of 1 "on" and 1 "off" giving 15 ft. per minute with the 60 ft. per minute mentioned above obtained without a timer. Avoidance of this excessive speed or the avoidance of the burning of the material by the use of lower speeds and the resulting increase of spots per inch generally forces the use of an interrupter.

Timing Schedules.—Figure 1 shows the timing combinations obtainable with 60-cycle power frequency and the two commercially available full electronic controls. For a given number of spots per inch and welding speed in inches per minute we intercept a curve of spots per minute or total time curve. This total time is the sum of the "on" time and "off" time. For example, if we wish to use 10 spots per inch and 72 in. per minute welding speed, we may make 720 spots per minute in any of several timing combinations. These combinations are 1 cycle on and 4 cycles off, 2 cycles on and 3 cycles off, 3 cycles on and 2 cycles off, 4 cycles on and 1

cycle off, each combination having 5 cycles as the sum of on and off time.

It is our recommendation that when welding soft steel in the range of the tabulated speed and gages, the "on" or "off" time never exceeds twice the other, and in a majority of cases best results are obtained with equal on and off time. For example, 2 on and 3 off, or 3 on and 2 off, is a much better combination than 1 on and 4 off, or 4 on and 1 off. This rule of thumb does not hold if dealing with coated soft steels such as galvanized steel, galvaneal, terne plate, etc., or special alloys.

Full electronic timing equipment should be used. The more obvious and well-known reasons are that mechanical interrupters have excessive maintenance and definite speed limitations as well as inaccurate periods of "on" and "off" time. Another important factor is the synchronous starting of electronic controls.

Welding Pressure.—The term "welding pressure" is a very ambiguous and misused phrase. Basically speaking, "welding pressure" as generally used should be called "static welding pressure" because that is the way it is measured. This pressure, as almost universally measured, consists of measuring the effort of an air or hydraulic medium in pounds per square inch on a piston of known area or the effort of a spring and then adding to this figure the component of the weight of the moving parts which increase the effective pressure. In the case of equipment where varying pressure is obtained by varying weights, the static welding pressure consists entirely of the weight of moving parts.

The pressure which actually does the welding and on which instantaneous values, the success of welding depends, can be truly designated as the "dynamic welding pressure." No commercial means are available for measuring this pressure at the present time.

Dynamic welding pressures are governed by five factors:

1. The pressure medium, i.e., air, hydraulic, spring.
2. Inertia, i.e., total weight and distribution of weight of moving parts of the pressure system.
3. Friction in pressure system.
4. Strength under compression at various temperatures of the material being welded.
5. Reaction on the pressure system by the "motor action" or "jump" of the current-carrying members during weld.

It is indeed fortunate for industry that soft steel with its wide plastic range can be welded with so many combinations of variables that for most practical purposes measurements of static welding pressure suffice as a yardstick for dynamic welding pressure. Greater accuracy of measurement and attention to design detail is necessary when welding metals with a narrow plastic range. Almost everyone in the profession of resistance-welding has experienced the impossibility of obtaining satisfactory welds using certain materials and schedules until the inertia and/or friction of the pressure system had been materially reduced.

As far as this article is concerned, the static pressures measured and recorded may be readily reproduced on commercial machines now available. Because of the necessity of using current carrying bearings and bands of standard size and weight, it is difficult to keep inertia to a low figure on seam welders. Static welding pressures recorded in this article include a weight of moving parts of approximately 280 lb. The pressures recorded are of sufficient value to weld two pieces of flat strip together. If the material is warped or poor assembly fits require a certain amount of pre-forming before weld-

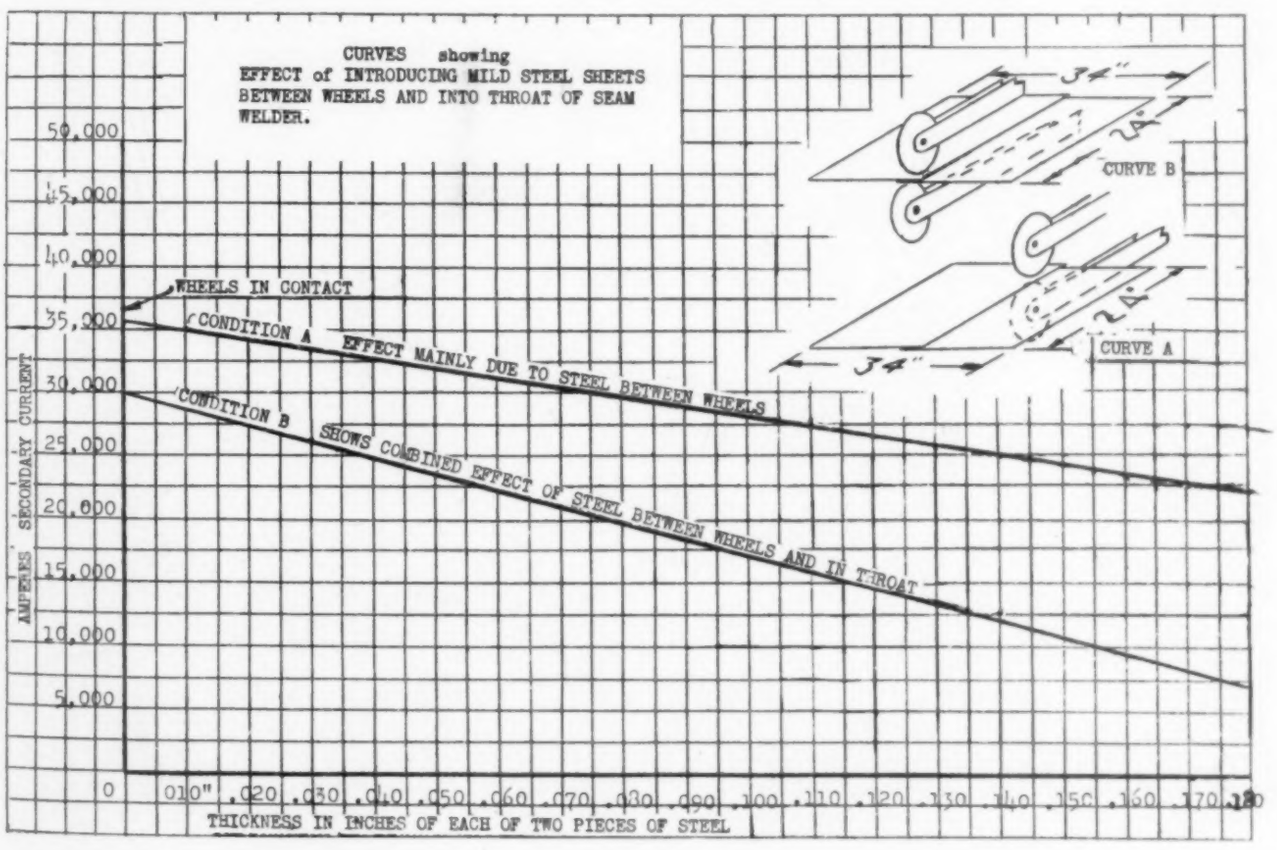

Fig. 2

ing, these pressures must be added to the recorded welding pressures.

Welding Current.—Inspection of data and charts included in this article pertaining to the welding of the various gages of material will indicate that no reference is made to kva., kw., primary voltage or primary current as such. These terms have no place in the recording of values of the different variables necessary to the welding of the material. They do pertain to the field of design of welders, welder characteristics or power demand but the use of them as a necessary or pertinent factor in the application data of the weld itself is evidence of a misunderstanding of the facts. While the formula I^2RT represents the heat *created*, a factor K must be added to indicate the variation of heat *required*, as thermal conditions change, such as the addition of more cooling water. Given a selected timing schedule, thermal condition and resistance of material, the remaining factor I of the formula I^2RTK is the welding or secondary current.

Seam Welding Wheels.—All the welding covered by this article was done using R. W. M. A. Class 2 alloy wheels made of a copper alloy of the heat-treated precipitation hardening type. Typical characteristics of this class of alloys are shown by the particular specifications following:

Electrical conductivity in % of copper	75
Hardness, Rockwell B	76
Proportional limit, lb. per sq. in.	36,000
Tensile strength, lb. per sq. in.	55,000
Elongation, %	15.0

The faces in contact with the work were of the widths indicated by the tabulated data. These faces had a very slight crown with rounded corners. The wheels were driven by friction rolls which served the additional important function of maintaining a proper and consistent wheel contact face, width and shape. The wheel diameters are indicated in tabulated data.

As heavier gages of steel are welded using heavier pressures and higher currents, the face widths of the wheels must of necessity be increased to avoid excessive unit pressure and excessive unit current density.

The rate of wheel wear is determined by pressure used, surface condition and analysis of the material being welded, wheel temperature as determined by values of welding current and amounts of cooling water, abrasion of work and drive rolls, and the material used for wheels.

Cooling Water.—During all welding, in obtaining data as recorded by this article, four jets of cooling water were used. One jet was located on each side of each wheel and directed at the point of weld. The water from the two jets on top of the work cooled the work more effectively than the two jets beneath the work. This is due to the effect of gravity assisting the coverage by water on the top of the work and is readily seen by the variation in discoloration of the top and bottom surfaces of the weld. An abundance of cooling water should always be used whenever possible in the interests of work quality and wheel wear.

Weld Width.—Examination of weld widths indicate that the width of the weld at a point on the center line between the two pieces welded ranges from $1\frac{1}{2}$ to 3 times the thickness of one piece of the gage being welded. The higher ratio of weld width to plate thickness occurs when welding the thinner gages and this ratio decreases as the material increases in thickness. The limit of commercially practical minimum wheel face width is approximately $\frac{1}{8}$ to $\frac{3}{16}$ in. because of excessive wheel wear. This explains the high ratio for the thinner gages. The weld width is always slightly less than the face width when commercially practical welding schedules are used. An estimate of weld widths being 80% of wheel width is approximately correct.

Table 1

Gage	Speed, In./-Min.	Secondary Amperes	Total Pressure, Lb.	Weld Width, In.	Wheel Width, In. Top	Bottom
24 (0.024)	392	13,900	600	3/32	1/4	1/8
22 (0.029)	392	14,700	600	3/32	1/4	1/4
20 (0.038)	392	17,900	600	7/64	1/4	1/4
19 (0.044)	300	19,000	800	7/64	1/4	3/8
18 (0.048)	220	20,400	1200	7/64	1/4	3/8
16 (0.062)	220	22,000	1400	1/8	1/4	3/8

Wheel diameters approximately 8 in.

TABLE 2

MATERIAL THICKNESS **Ga.	Inches	Spots Per Inch	Welding Speed In/Min.	TIMING SCHED. Cycles On	Off	Welding Current Amperes	Press. Pounds	WELDING WHEELS Dia.
22	0.031	12.5	48	1	5	14,500	600	8
22	0.031	12.5	48	2	4	11,800	600	8
*22	0.031	12.5	48	3	3	10,800	600	8
22	0.031	12.5	48	4	2	10,200	600	8
22	0.031	12.5	48	5	1	9,800	600	8
22	0.031	12.5	96	1	2	15,100	600	8
*22	0.031	12.5	96	2	1	12,200	600	8
22	0.031	12.5	144	1	1	15,700	600	8
20	0.039	12.5	48	1	5	19,000	600	8
20	0.039	12.5	48	2	4	14,000	600	8
*20	0.039	12.5	48	3	3	12,300	600	8
20	0.039	12.5	48	4	2	11,500	600	8
20	0.039	12.5	48	5	1	10,900	600	8
20	0.039	12.5	96	1	2	19,600	600	8
*20	0.039	12.5	96	2	1	15,000	600	8
*20	0.039	12.5	144	1	1	20,200	600	8
18	0.049	12.5	36	2	6	16,500	750	8
18	0.049	12.5	36	3	5	14,200	750	8
*18	0.049	12.5	36	4	4	13,000	750	8
18	0.049	12.5	36	5	3	12,200	750	8
18	0.049	12.5	36	6	2	11,700	750	8
18	0.049	12.5	36	7	1	11,400	750	8
*18	0.049	12.5	72	2	2	17,600	750	8
18	0.049	12.5	72	3	1	15,000	750	8
*18	0.049	11.1	108	2	1	19,000	750	8
16	0.062	12.5	36	2	6	20,200	750	8
16	0.062	12.5	36	3	5	17,400	750	8
*16	0.062	12.5	36	4	4	15,400	750	8
16	0.062	12.5	36	5	3	14,000	750	8
16	0.062	12.5	36	6	2	13,100	750	8
16	0.062	12.5	36	7	1	12,700	750	8
*16	0.062	12.5	72	2	2	20,700	750	8
16	0.062	12.5	72	3	1	17,100	750	8
*16	0.062	11.1	108	2	1	21,400	750	8
14	0.078	12.5	24	3	9	19,600	900	8
14	0.078	12.5	24	4	8	17,800	900	8
14	0.078	12.5	24	5	7	16,300	900	8
*14	0.078	12.5	24	6	6	15,100	900	8
14	0.078	12.5	24	7	5	14,200	900	8
14	0.078	12.5	24	8	4	13,600	900	8
14	0.078	12.5	24	9	3	13,300	900	8
14	0.078	9.4	48	3	5	20,400	900	8
*14	0.078	9.4	48	4	4	18,600	900	8
14	0.078	9.4	48	5	3	17,100	900	8
14	0.078	9.4	48	6	2	15,800	900	8
*14	0.078	12.5	72	3	1	21,300	900	8
12	0.109	12.5	24	4	8	21,300	1000	8
12	0.109	12.5	24	5	7	19,200	1000	8
*12	0.109	12.5	24	6	6	17,400	1000	8
12	0.109	12.5	24	7	5	16,200	1000	8
12	0.109	12.5	24	8	4	15,300	1000	8
12	0.109	8.3	48	4	5	21,900	1000	8
*12	0.109	8.3	48	5	4	20,000	1000	8
12	0.109	8.3	48	6	3	18,100	1000	8
*12	0.109	12.5	72	4	2	22,700	1000	8
11	0.125	12.5	24	4	8	25,300	1200	8
11	0.125	12.5	24	5	7	22,700	1200	8
*11	0.125	12.5	24	6	6	20,800	1200	8
11	0.125	12.5	24	7	5	19,200	1200	8
11	0.125	12.5	24	8	4	18,000	1200	8
11	0.125	8.3	48	4	5	26,600	1200	8
11	0.125	8.3	48	5	4	23,200	1200	8
11	0.125	8.3	48	6	2	21,400	1200	8
11	0.125	12.5	72	4	2	27,300	1200	8

** U. S. S. Gauge

The following tabulations are the data for continuous welding for clean mild steel without an interrupter at the maximum practical speeds:

Anyone of these gages can be satisfactorily welded continuously at lower speeds than those shown, in which case the current will, of course, be lower.

For first-class welds in mild steel, we would recommend welding without an interrupter up to and including 20 gage. The heavier gages shown above can be welded, however, but surface appearance is not as good as when an interrupter is used, and we recommend that for best results interrupted welding should be used.

Table 2 shows conditions for welding various gages of mild steel at various speeds when an interrupter is used. The set-ups marked with an asterisk are recommended as being set-ups which give excellent welding results. However, all the schedules give gastight welds and various special applications may make some other combination than that marked with the asterisk desirable.

For speeds not shown, it is believed that estimates of the required current can be readily made from the figures which are given.

In selecting a seam welder capable of making a given weld, the mechanical and welding speed considerations have been previously discussed.

From the electrical point of view, it is only necessary that the machine be capable of supplying the necessary welding current at the necessary duty cycle without any of the component parts of the machine overheating. However, the requirements to fulfil these conditions are affected by several factors making it difficult to lay down a single rule by which required machine capacity may be determined.

For example, duty cycle is determined not only by the "on" and "off" time of the actual weld but is also affected by the time it takes to load and unload the machine. Another factor which has a very appreciable effect on the permissible loading of the machine is the averaging period over which the duty cycle is determined. For example, tests have shown that it takes about four hours for a seam welder to reach its maximum temperature rise at full load due to the great mass of the current-carrying parts. Therefore, a machine may be loaded considerably beyond its rated capacity and run at this increased load for possibly a full hour without excessive heating, and at the end of this, only a comparatively short time without the power on, will bring the welder back to its ambient temperature.

These factors must all be taken into account in making seam welder recommendations so that the recommended machine will fulfil all the customer's requirements and yet not be heavier and more expensive than necessary.

As far as being able to obtain the required current is concerned, this is primarily determined by the impedance of the secondary circuit with the work *in place;* it only being necessary to have sufficient voltage to cause required current to flow through this impedance. The impedance is affected by the throat depth and arm clearance of the machine and also by the work which is in the throat of the machine. This, of course, has a very appreciable effect and an idea of its magnitude may be obtained from the curve, Fig. 2.

Arc Welding Saves Michigan Gravel Company $12,114 Maintenance Costs Each Year*

AN AVERAGE of $12,114 is saved each year by the Construction Aggregate Company of Ferrysburg, Michigan, by repairing their three Link Belt cranes by electric arc welding. These cranes dug more than one million tons of gravel last year. At the end of each operating season these machines are stripped to the frame and the parts inspected and repaired. Below is a cost comparison chart kept by the Master Mechanic and the Welding Supervisor illustrating the enormous savings to the company from arc-welding repairs.

Part	Cost	Welding and Machining	Savings
1 Traveling ring gear	$ 600	$150	$ 450
8 Stub-axles at $111	888	200	688
2 Drive axles at $150	300	60	240
1 Take-up axle at $300	300	60	240
10 Wheels at $75	750	100	650
2 Drive sprockets at $125	250	50	200
2 Take-up sprockets at $150	300	50	250
50 Traveling lugs at $20	1000	125	875
1 Center pin	275	25	250
1 Head pin	20	5	15
Seven pins and small accessories	200	20	180
	$4883	$970	$4038

Savings for 3 cranes, 3 × $4038 = $12,114.

Mr. Barrett, Welding Supervisor, says, "We have proved by actual experience that the wearing life of these welded parts averages 50% longer wear than a new part. For repair of the three Link Belt cranes we used approximately 2¼ tons of welding rod. These figures are based on winter repair and do not include the savings on breakages and repairs during actual operation."

* These cost-comparison figures were reported by Henry Barrett, Welding Supervisor of the Construction Aggregate Company, in his prize-winning entry in the Hobart Arc Welding News Contest.

The Training of Welding Operators*

By T. B. Jefferson†

THE training of welding operators is a subject that can be discussed with many points of view. The welding industry's problem of supplying our defense contractors with trained, competent welders is equally as important as the problem of supplying these same defense contractors with welding equipment or efficient welded designs. In fact, welding equipment and designs will be of little value if a shortage of skilled welders should develop in the near future.

This Society has long been aware of these training problems and the subject of training welding operators has been discussed frequently at the Society's national meeting. Usually, however, these papers have been presented by educators or operators of welding schools, consequently the story naturally has been presented from the educator's point of view.

Today I hope to cover the subject of the training of welding operators from a slightly different angle—the employer's angle. The opinions to be expressed are based upon my actual experiences, first, as an employer of several hundred welders and, more recently as an observer of the happenings in welding schools and the welding industry, as the editor of *The Welding Engineer*.

The importance of the welder in the time of national defense has been established by the fact that over a year ago England excused welders over 21 years of age from military service. In this country we find that in every industrial plant engaged in defense production involving metal working there is to some extent the use of welding and cutting and employment of persons skilled in these crafts. The result has been that an intensive training program has been undertaken under government and private sponsorship to insure a further supply of skilled welders.

It is only natural in such a speeded-up program, for many false starts to be made. Welding training courses are started without serious thought as to requirement or consequences. It should be remembered that in every program for the training of welding operators, whether it is in connection with the training plan of a welding school for training hundreds of welders or an industrial plant training one welder, the program is confronted with three problems. These three problems evolve themselves into the three principal points affecting the success of every training program. They are:

1. The student.
2. The teacher.
3. The equipment.

The Student

So that our thoughts might follow a definite line, let us consider operator training, first from the student angle.

As plant managers and executives you are looking for welders. These welders may be experienced men, thoroughly trained in welding; or perhaps your company is inaugurating its own training program and will train welding students to suit the needs of the plant. In either case your ultimate welder will have received training of some nature before being classified as a welder. In the event you elect to train your welding personnel, what kind of a man are you going to select as a student?

I believe you will all agree that great care should be taken in the selection of the welding student. Too often an applicant is admitted to a welding course without any thought being given as to whether he is likely to become a satisfactory welder. Part of this laxity may be contributed to the principles upon which some welding schools have been founded—the principles of operating a school for the money that is to be obtained from the students rather than for a fair profit while dispensing the knowledge the student is obtaining from the school. It is fortunate for both the student and the industry, that a majority of the country's welding schools are operated with their first thoughts directed toward the student's welfare.

To avoid the risk of stepping on someone's toes, let us assume that we are interested primarily in a training plan for an industrial plant. In this event it is vital to the company's interests that due consideration be given the type of individual which is selected for welder training so that only those candidates who are most likely to succeed will be selected. There are many reaons for this careful consideration; one is that to train a welder it costs the company between 25 to 30 cents per hour for material alone. To this cost must be added charges for instructors, equipment depreciation, as well as repair and maintenance. It may be seen that even on a non-profit basis student training is costly.

Another reason—a more important one—is that the entire efficiency of future welders and the welding industry depends upon the intelligent selection of students. If the trainees selected are of low intellect and poor mechanical aptitude, a poor welder is most likely to be the result. On the other hand, if these qualities are high, the high quality of workmanship and the initiative of subsequent higher type of welder will result in greater progress in the welding industry.

What qualities and characteristics in a student are most likely to make him a good welder? The answer is somewhat the same as the answer to the question, "How high is up?" The making of a welder from a student depends upon many variables but by careful analysis the probabilities of the outcome may be gaged fairly accurately.

The first thing that should be determined about our student is: Do we have a trainee who is trainable? Just as there are those who will never learn to drive a car or play a piano, by the same token there are those who cannot learn to weld. If after a few hours of instruction your trainee proves to be the untrainable type, you will save time and money for both the trainee and the company if you tactfully suggest he learn some other trade. An investigation of the trainee's industrial experience, his attitude and his mechanical aptitude will give an insight as to his trainable potentialities.

* Presented at Western Metals Congress, AMERICAN WELDING SOCIETY, Biltmore Hotel, Los Angeles, Calif., May 19–22, 1941.

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If we feel we have a trainable trainee, what other characteristics should we look for in our student? A study of welders indicates that there are probably three qualities which should be considered before training is begun or at least before it has advanced too far. These qualities are:

(*a*) Mechanical aptitude.
(*b*) Physical characteristics.
(*c*) Attitude.

Mechanical Aptitude.—Mechanical aptitude is believed to be the most important quality, aside from trainability, to be sought in a trainee. A student must possess ability and mechanical inclination; without it he will probably find it difficult to become proficient. Practice coupled with skill (mechanical aptitude) is the only way to obtain proficiency in welding just as practice and skill are the only way to become proficient as a machinist, a toe dancer or an artist. Without skill a trainee will never become proficient or happy in his work.

Physical Characteristics.—What phvsical characteristics go to make the best welders? Observation leads one to believe that there are some important physical factors which definitely affect the ability of a trainee.

First of all, to become a proficient welder a trainee should possess normal coordination. His fingers must be able to follow quickly and easily the thoughts of his mind.

He must have normal mentality. This does not mean that he is to have a specific intelligence quotient rating or that he be given an IQ test. It does mean, however, that the trainee should have a normal mind which will absorb information. Likewise, his mind must have a normal capacity to learn. If he is capable of visualizing and has been trained to appreciate relative values of size and perspective, there will be little doubt as to the capabilities of the student.

The senses, too, are important! A trainee should have normal hearing and vision which is normal or has been corrected to normal. If the vision of a trainee has been corrected with glasses it will be found that weak eyes are not a handicap. Experience has shown that welding is not harmful to the eyes; however, some welders have injured their weakened eyes by straining them, trying to see through heavy welding lenses unaided by corrective lenses. If the trainee has poor eyesight, see that he wears glasses under his helmet or goggles; better work with less headaches for all concerned will be the result.

The physical build of trainees is something which some plants are beginning to consider. Only persons of average size or build are employed. This is not because average-sized persons are capable of producing more work than other persons but because they produce less work stoppage. It has been found that when a person of unusual height, unusual weight or one having some other outstanding physical characteristic goes through the plant, fellow workers frequently stop and look. Naturally, this "stopping to look" on the part of the entire plant slows up production. Consequently the tendency is to avoid the unusual type in both trainees and employees.

Age is a problem which creeps upon all of us and is also a problem in a program for the training of welding operators. In some instances the ages of trainees who are to be trained as all-around welders have been limited to those prospects between 18 to 35 years old. The contention is that "you can't teach an old dog new tricks;" for this reason prospective students over 40 are looked upon with disfavor. The feeling is that persons over 40 seeking to learn welding have perhaps experienced periods of unemployment in recent years. If they have been employed it is very likely that it has been in a field that is vastly different than the welding industry. In either event it is felt that the applicant will possess only a fair initiative and probably would not become a proficient welder.

It is hoped that these opinions on a trainee's physical characteristics will not result in any feeling that certain persons are being discriminated against in the welding field because of age or other features. These are merely factors we all must face in this day of modern business and streamlined production.

Attitude.—The third of our trainee qualities which should be ascertained is attitude—attitude toward the company for which he is to work, toward his work and toward his fellow worker. Naturally company loyalty is to be sought from every employee; for this reason this quality should be sought first in the prospective trainee. In this day and age we hear a lot about personality and, though some may think it strange, your trainee must have personality, for personality frequently affects attitude—not necessarily the personality of the super salesman, but he must have social acceptance so that he can meet and greet the public. His temperament and spirit of cooperation must also be considered when determining the trainee's attitude. A welder is frequently called upon to work in close cooperation with fellow workers so he should be one who will cooperate and one with whom it is easy to get along.

So much for our trainee. While these specifications cannot be adhered to rigidly, it is believed that they will prevent some attempts "to place square pegs in round holes." As is often the case, considerable time is wasted in trying to place a trainee in some position only to find later that he is unsuited. If the aforementioned suggestions help reduce the frequency of these unsatisfactory happenings, they will have accomplished their purpose.

The Teacher

Our next concern is our teacher. As we all know we must have a successful teacher but what are the requirements of such a teacher? According to the Syracuse Bulletin a teacher to be successful must have: the education of a college president, the executive ability of a financier, the humility of a deacon, the adaptation of a chameleon, the hope of an optimist, the courage of a hero, the wisdom of a serpent, the gentleness of a dove, the patience of Job, the grace of God, and the persistence of the devil.

Now it is hardly believed that such requirements are necessary to teach welding in an industrial plant or commercial trade school. It is not even necessary that he be a skilled teacher but he must know how to teach. Training progress is often impaired by two kinds of teachers—"those that can, do; those that can't, teach" and "those who teach for 5 years and are no good for anything and then after teaching for 10 years are not even good for that." This does not mean, however, that all teachers become antiquated with years of teaching, though they are likely to if they fail to keep up with the rapid changes in the industry. Teaching is a varied profession covering many fields. It should be remembered that supervising is teaching and that salesmanship is teaching; in either case ideas are being presented to enhance the knowledge of another.

How can we recognize a good teacher?

A good foreman will make a good teacher. Foremen often hate to be tagged as teachers but every foreman at times has had to give instructions to a new employee or explain a new job and as soon as he undertook these tasks he became a teacher.

A good welding teacher must be a master welder—he must be a topnotch in his trade, one with plenty of experience and one who is qualified to seek out difficult answers and to conduct practical demonstrations.

A teacher must have the *ability to organize*, for proper organization is the backbone of every training course. Students must be organized so that they will get the proper start into the course of instructions; instructional material must be organized so that it will be presented in an orderly fashion. The effectiveness of these organization jobs is dependent upon the instructor's ability to organize.

Another quality and probably the most important for a good teacher is the *quality to teach*—the ability of the teacher to transfer his thoughts to the student. A teacher who cannot pass his thoughts on to the pupil will find it very difficult to teach even the most apt of trainees.

We must remember that in the training of welding operators the teaching process is identical whether there is one or fifty trainees and irrespective of whether the training is to be carried out in the shop of an industrial plant or in a commercial trade school. In any such training program there are four steps to be followed:

1. Preparation of material.
2. Presentation of material.
3. Practice.
4. Examination.

Preparation of Material.—The preparation of material presents some serious problems particularly in connection with our defense program.

To prepare a training program to meet the welding requirements of defense contractors it is necessary to investigate the welding application applicable to these industries' various fabricating processes. Only when these points have been determined is it possible to correctly emphasize certain portions of the training program so that the trainee will be qualified for the fabricating job at hand.

After the principal points of the training plan have been settled, another problem appears. Should the trainee be trained on an all-at-once basis in which all the fundamentals are taught at once, after which he would master these basic principles by repetitive review; or should he be trained step-by-step in which case each principle is mastered before undertaking another?

Our defense program has further complicated this phase of the welding training by questioning as to whether trainees should be given comprehensive training or single operation training. By comprehensive training the student is trained to become an all-around welder familiar with all metals and capable of welding in all positions. In single operation training a student is taught in a much shorter time and usually is qualified to do only one type of welding, e.g., downhand welding on steel plates.

The problem of comprehensive or single operation training is one that will most likely be solved by those conducting the training program. Industrial plants will indoubtedly prefer the single operation type of training because by this teaching method a trained welder is obtained after a shorter and less costly training period. Likewise single operation welding is ideally suited for production work. The disadvantage of single operation training is that instead of having developed a proficient welder the training course gives industry a mechanized man trained to act in only one way. Such training does not lead to proficiency or tend to make a booster for the welding industry. Instead, it will likely lead the trainee to disappointment when our country settles back to a normal business pace and our single operation welder learns that he is not a welder qualified for big money but only a semi-skilled laborer who knows a little about welding.

To counteract this thought there will be presented the argument that if the trainee is given comprehensive training in all phases of welding it will be very unlikely that he will be called upon to demonstrate his technique in all the welding processes in any one industrial plant. Consequently it is claimed that comprehensive training is a waste of time. It is further argued that in the short time devoted to a comprehensive training course it would be impossible for the trainee to become proficient in all applications. Even though the trainee has sufficient training time, it is also unlikely that he would become a welder of such high quality as to be considered proficient in all applications of the welding processes.

The outstanding point in the favor of single operator training is the fact that it will give our defense industries the greatest number of trainees in the shortest period of time. By this system of training it is possible to supply a prospective employer in a very short time with a group of operators proficient in a specific application.

For such a training plan to be successful, however, it is absolutely necessary that the requirements of the employer be ascertained and that the training program be prepared to meet these requirements. In this system of training it is important, too, that the trainee be given employment as soon as the desired proficiency is attained; otherwise the trainee, who has not had sufficient training to have thoroughly embedded welding habits, might forget his training while awaiting employment.

Irrespective of the type of training it must be remembered that all men in a welding course will not proceed at the same pace. In the preparation of material the course should be planned so that the class can be kept as uniform in its progress as possible.

Presentation of Material.—The manner in which the material in a training course is presented naturally is vital to the success of any such course. Presentation of material to be successful should follow four well-defined steps:

1. The lecture: Ofttimes the lecture may prove to be the most difficult part of a training course from both the standpoint of teacher and trainee. It must be a *planned* classroom lecture; the instructor must have a planned, organized presentation. Some feel that this lecture need not be given by the same instructor who gives the shop work but I believe as a rule more satisfactory results will be obtained if the same person handles both the lectures and exercises.

2. Outside study: In most training programs it is found beneficial if the trainee is required to do outside study in connection with every lecture. This is true in welding training too, in which case outside study is on subjects which either review or supplement the lectures.

3. Demonstration: It is during the demonstration period that the instructor comments on important points which were referred to in the lecture. These comments are then supplemented by advice which can best be given only by demonstration.

4. Practice of exercises: In these periods the student should practice various exercises to learn to apply the knowledge given him in the three preceding steps of the lesson and to acquire manual dexterity.

Practice.—Practice or the application of those principles the student learns play an important part in the final success of the training program. It is here that the trainee by trial and error or, more truthfully, by trial and success builds confidence in his ability to become a proficient welder. Each successful accomplishment builds more self-confidence and results in a further desire to do better work and to learn more about what he is doing. It is during this phase of the training program that the habits of the trainee will be acquired. In view

of this the instructors should take care to see that the correct habits are acquired from the beginning. We must remember that habit is merely an established practice and for this reason the lesson must be learned the right way the first time and repeated in the right way until the habit is thoroughly established. After habits have been established, the trainee should then be placed on his own and be allowed to think out his own problems.

Examination.—The final stage of a training program is the examination phase in which the instructor may determine by testing the results which have been obtained from his teachings. In this phase of the training the teacher must have a good understanding of human nature. He must know when to pat the trainee on the back, when to criticize and when to let the student plan his work.

The Equipment

In conclusion I would like to discuss briefly the equipment of a school for training welding operators. I shall not attempt to advise any one regarding the amount of equipment required for a welding school or the amount of floor space that should be available for each trainee in the class.

I would like to point out, however, the following: The best equipment you can buy is none too good for your welding school. Be sure to get equipment that you can be proud of, for it not only builds up the morale of the school but also of the students and the management. Student training subjects equipment to more severe service than actual shop work.

Gas Company in Middle West Erects Unique Storage Plant

By A. F. Davis*

A NEW $1,000,000 gas storage project, which provides, in three spherical tanks, a storage capacity equivalent to one hundred and fifty conventional gas holders was made practicable by arc-welded construction at the plant of a midwest gas company in Cleveland, Ohio.

The unique feature of this new project is the reduction ratio of 600 to 1 in liquefaction. In employing the cascade refrigeration process, the new plant stores the gas at extremely low temperatures (248 to 250 degrees below zero), thus introducing new metallurgy.

The storage tanks consist of three arc-welded alloy steel spheres 57 ft. in diameter, 70 ft. high over-all, each sphere having a storage capacity of over 50,000,000 cu. ft.

Each sphere is, in reality, two spheres in one. Within an outer shell and separated from it by 3 ft. of cork insulation is a nickel alloy steel sphere in which the gas is actually stored. This inner sphere actually "floats" upon the cork insulation, a feature which allows "working" during expansion and contraction.

* Vice-President, The Lincoln Electric Company, Cleveland, Ohio.

Fig. 1—Three Arc-Welded Steel Gas Storage Spheres, Which Provide Storage Capacity of 150,000,000 Cu. Ft. of Gas. Photo Shows Spheres Partially Erected

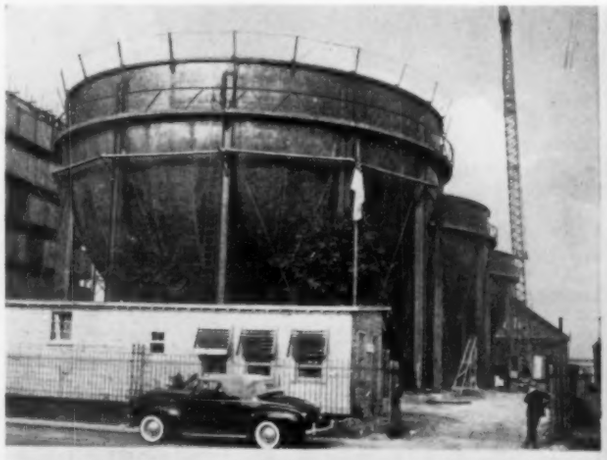

Fig. 2—Overhead Welding of Bottom Segment of Outer Shell of Storage Sphere

Fig. 3—Arc Welding a Clip Angle to Inside of Outer Shell for Holding Scaffolding for Welders

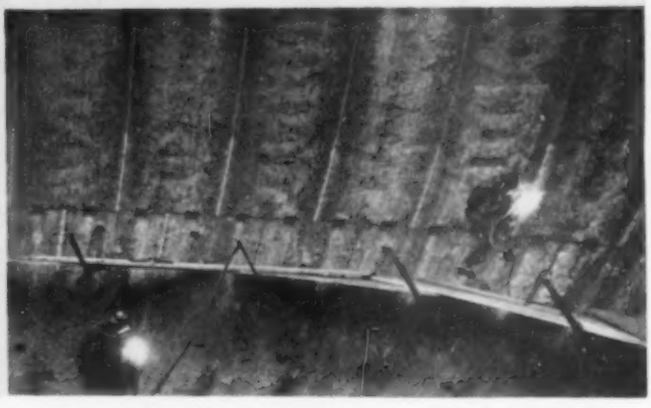

Fig. 4—Arc Welding the Seams of Outer Shell from Inside of Sphere. Multiple Bead Shielded Arc Welding Is Used Throughout

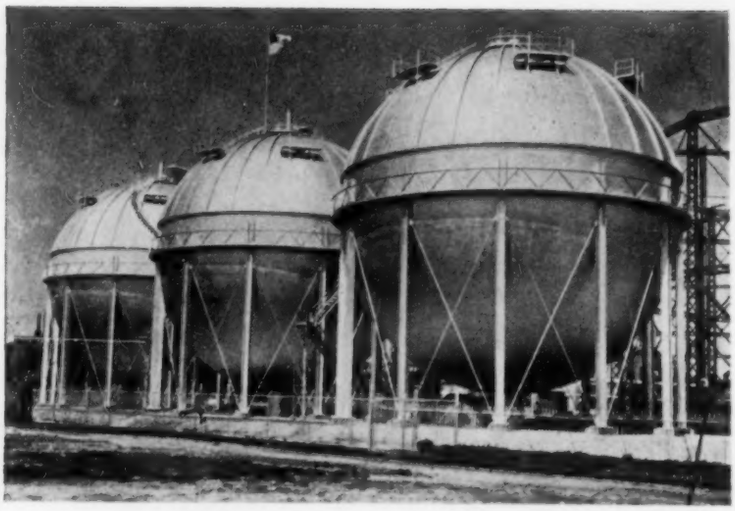

Fig. 5—The Three Arc-Welded Gas Storage Spheres Completed

Each sphere is supported by 12 columns fabricated of wide-flange rolled-steel sections. These columns have their flanges cut away at the top to conform to the contour of the shell. They are connected to the shell by fillet welds at junction of flange to the shell plating. Arc welded to the column web is a T-bracket supporting a balcony which completely encircles the sphere.

All steel for the tanks was entirely formed in the shop. The shell of the sphere, consisting of 128 separately formed segments, was fabricated by cutting steel plate and pressing it to the proper curvature. It is interesting to note that all of these segments were so accurately formed that no adjustments were necessary during erection. This is believed a remarkable feat considering the thickness of shell plating used and the form to which fabrication was necessary.

Erection of a sphere began with placing the 12 columns upon concrete footings. Erection of the balcony and platform followed, then the center cylindrical section, utilizing temporary bolted connections. Then, working down from this center section, the segments of the sphere were placed utilizing clip angle hangers which held the segments in place. After all steel of a tier was in position, tack welds were made at various points followed by finish welding of the inside seams. The clip angles were chipped away at an early stage in the welding and the inner seams were welded in four beads. Welds were chipped away on outer surfaces and seal-welded. The thickness of the outer shell, consisting of mild rolled steel, is $^{7}/_{16}$-in. All welding was done under Hartford Insurance Inspection and all welders were qualified in accordance with the A. S. M. E. Code for pressure vessels.

With the lower half of the outer shell completed, application of the cork insulation was carried out, skewering the layers of cork together. Then followed application of asbestos paper, a nickel steel backing up strip for the welds on the inner sphere (which was tack welded to the segments of the alloy sphere before erection), finishing with arc welding on the inner shell seams.

The lower half of the inner sphere, which is constructed entirely of nickel steel $^{3}/_{8}$ in. and $^{7}/_{16}$ in. thick, was then erected and welded. All welds were beveled to as small a vee as possible, the bevel not exceeding 30 degrees at any point. With completion of the two lower halves, the upper half of the inner sphere was then erected and welded, the upper half of the outer shell placed and welded, then the 3-ft. space filled with granular cork insulation. Erection of the upper portion of each sphere consisted of working from the center cylindrical section upward, placing each tier of segments in order. This work was carried out utilizing the same temporary bolted clip angles until all steel was in position.

Erection of these three spheres represents a new industrial advance made practicable by welded construction.

The Gas Machinery Company, Cleveland, Ohio, was the general contractor for the project, and Pittsburgh-Des Moines Steel Company of Neville Island, Pa., were the sub-contractors for the fabrication and erection.

(*Continued from page 601*)

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(*Continued on page 644*)

Fundamentals of Structural Welding Design*

By C. Harold Louree†

THE literature of structural welding is too extensive to be fully reviewed in a short talk like this. It will be my aim to present the essentials of the design of welded steel construction, to correlate design with shop-practice requirements in such a way that the designer and the shop man may each better understand the other's problems.

Fully competent design must be predicated upon a knowledge of the behavior and properties of engineering materials under the conditions that attend construction operations as well as conditions of service. Too many engineers, however, have been content to use more or less standardized details under all conditions that arise, and to assume blandly, and confidently, that their design assumptions will be fulfilled perfectly.

Materials for Design

Designers have a habit of assuming that the material in their structures comes miraculously through mill, shop and erection operations without any of it having been stressed or deformed beyond the elastic limit, and that it arrives in final position, practically free from stress until it assumes the loading for which it was computed.

Nothing is further from the truth, regardless of whether the material be steel, concrete, wood or some other material. In any kind of steel construction, the material, in passing through various stages of mill and shop operations, is hot worked, cold worked, bent and formed. It is at all times in a condition of balanced localized internal stresses with peaks that often reach yield-point magnitude. Differential rates of shrinkage during cooling, after rolling, set up such stresses. Then during and after erection the steel is unavoidably subjected to incalculable secondary and concentrated stresses until it yields and becomes adjusted to service conditions, still in a condition of internal stress of yield-point value at some points. That is why specifications for structural steel have requirements for ductility and other properties that permit the material to yield locally and relieve these local balanced, secondary stresses as load stresses are induced, so that the two will not combine to cause structural damage.

These facts might be thought of as cause for great apprehension, if viewed with no knowledge of the behavior of structural steel, and if it were not for the excellent experience record of the reliability of steel construction.

Several facts about the stress-strain curve for a ductile carbon steel are often forgotten by structural engineers. The deformation up to the yield point is very small, something like 0.10%. It is found that the deformation up to the yield point (mostly elastic) is only about $^1/_{22}$ of the total deformation to the end of the "plastic" stage in which deformation takes place without increase in stress. This means that when a *self-limiting* condition causes a stress of yield-point value and an accompanying deformation that is perhaps somewhat more than yield-point deformation, and this condition is followed by a loading of the member, then only a very small amount of the available stretch in the plastic stage is sufficient to relieve the initial stress.

By releasing the load and then applying it again at several points, it is demonstrated for any of these points that part of the total deformation (which is mostly permanent set) is an elastic portion approximately equal to that which occurred before the yield point. The assumed initial stress corresponding to this elastic deformation is relieved as loads come onto the structure. Of course this is true only when the initial stress results from a self-limiting condition such as shrinkage or self-limiting rotations of the ends of members.

The properties of ductility and toughness in steel are largely responsible for its versatility and superiority in being able to adjust itself without structural damage to the requirements of practicable construction operations.

Harassing as it may seem to some engineers to think of the materials in their structures being subjected to strains that do not appear in their stress computations,

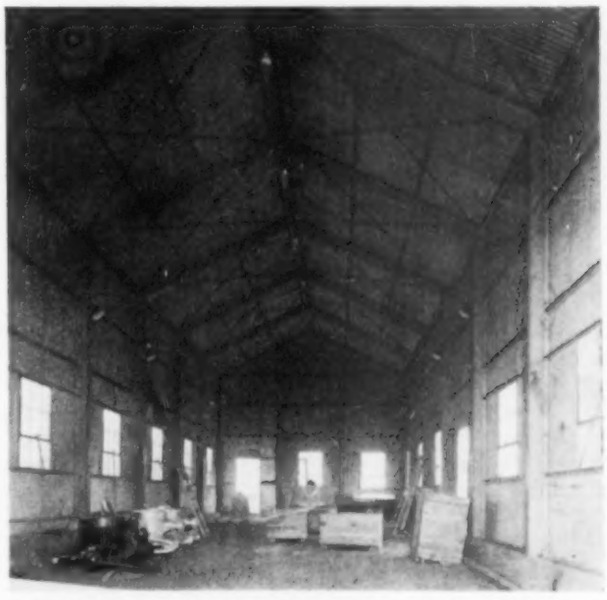

Fig. 1—Rigid Type Construction Used in a Sectional Type Steel Building
24 Ft. Span—18 Ft. Side Walls

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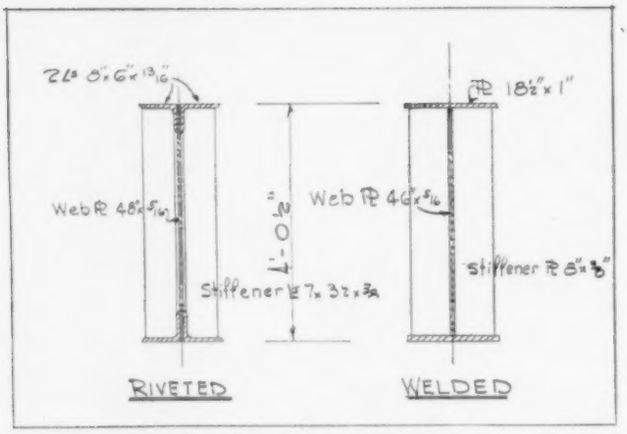


Fig. 2—Simplicity of Welded Girders

they must become reconciled to actual facts for an intelligent use of these materials. Whether they be steel, wood, concrete or other materials assumed to behave elastically, there actually exist very high secondary stresses due to differential shrinkage in cooling, drying or setting up, and due to plastic flow or permanent yield, etc., that could be viewed with equal disquietude, if not well understood.

Fortunately, in most cases no serious difficulties are encountered despite neglect by the designer to recognize fully the behavior of his materials of construction, because he uses for the most part details that have been found to stand up in practice even though they may, on the one hand, be grossly wasteful of material, or, on the other hand, be encroaching seriously upon the factor of safety. If a special detail gives trouble, the conclusion usually is merely that it is a bad detail and should be avoided in the future, whereas there is really a fundamental reason for the misbehavior, that is directly related to the natural behavior of the material.

Steel will stretch or deform a considerable amount after passing the yield point; but if it is called upon to deform too much, then real structural damage becomes imminent. If the form of a detail, or the presence of small cracks, or other serious defects cause deformations to be restricted to comparatively small areas or volumes of metal, there is no opportunity for the ordinary mechanisms of behavior to occur, and a ductile material may behave in a brittle manner before relief can be furnished through plastic flow or stretch.

Secondary stresses may be caused by differential shrinkage in mill or shop operations by cold working, by such partial restraint against end rotations of beams as occurs with standard "flexible" end connections, by sharp corners or by other conditions not recognized in design computations. Differential shrinkage stresses are nearly always quite highly localized and balanced, because areas subjected to tension are adjacent to areas under compression, and the total internal stress across a section is zero if there are no external forces acting at the ends of the member.

These secondary stresses are usually self-limiting and are relieved (because they are not caused by external forces which could follow up and continue the stress after yield has taken place), provided the metal is not prevented from behaving in a normal manner (by circumstances such as have been pointed out) and providing it is not called upon to deform an excessive amount.

Designers and shop men, alike, should be familiar with these properties of steel, both within the elastic range and beyond it, so they will understand the limitations of whay may be expected of the behavior of steel and thereby avoid difficulties that might otherwise be experienced from time to time.

With this in mind we will now consider some fundamentals of welding design; design-fabricated members as well as connections specially for welding, dismissing riveted prototypes from mind. Overlapped material, necessary in riveted work, is often unnecessary and undesirable in welded details; e.g., plain bar web stiffeners for beams and girders are more efficient than angles.

Wide Variety of Joints and Connections

A structural designer whose experience has not included welded construction is unlikely to realize at first what a wide variety of welded joints is available. This wide choice increases opportunities and makes it possible to develop many useful designs for which riveting offers no counterparts, but it also makes standardization more difficult and imposes a higher order of technical duty upon the detailer. For some classes of welded structures a far greater skill is required for detailing the joints than for designing the members (Fig. 6).

End connections of beams are the most numerous joints in building construction, and they account for more than half the total welding used in framed structures. Beam splices, column splices, connections for brace members, roof truss connections and gusseted joints for bridge trusses and heavy building trusses are other commonly occurring details.

Visualize all construction operations while designing a structure, and detail fabricated parts and connections with a planned sequence of welding in mind which will permit a control of distortion and shrinkage stresses.

Expansion and Contraction

Factors which affect expansion and contraction or distortion in welded structures are: Rigidity of members, speed of welding, sequence of welding, amount of heat used.

There are a few physical laws or facts which must be kept in mind at all times. Some of these are so obvious it may seem unnecessary to mention them, but a statement of these facts will bring to mind the items to be considered. These are:

Metals expand when heated and contract when cooled. The total expansion is dependent upon the length heated and the temperature change.

Weld Size	3/16	½	5/8	¾
Unit Stress	3000	4000	5000	6000
Ratio	1.0	1.33	1.67	2.0
Area	.070	.125	.195	.281
Ratio	1.0	1.78	2.78	4.0

Fig. 3—Size of Fillet Welds

This is sometimes ignored in discussion of welding, that is, slight account is taken of heating of plates or parts, only the bead being considered. Steel is elastic up to a certain value of unit stress; above this it yields, or plastic flow of metal or permanent deformation occurs.

As a summary of the factors involved and what might be termed general rules the following may be stated:

Stresses are set up in plates and shapes by rolling, shearing and forming. The partial release of these during welding may be a controlling factor. Stresses and warping caused by welding may be divided into two groups:

1. Those which occur during welding, or transient stresses or warping.
2. Final stresses or warping which remain when part is completed and cooled.

It is to be noted that the final *external* deformation is usually the most troublesome one and, further, that the amount of deformation does not necessarily indicate the stress value as this deformation is dependent upon restraint, stiffness, stress distribution and plastic flow.

All other things being equal, an increase of speed will slightly increase the warping. A small number of passes result in lessened warping.

Step back and skip step back welding will reduce locked-up stresses and warping due to more uniform distribution of heat and greater rigidity of part during welding.

It is advisable to weld from a point of restraint. The part will expand and, if unrestrained or nearly so, will be free to move.

Clamping will reduce warping and is more effective when welded parts are allowed to cool in clamps.

Stresses may be relieved by heat treatment *or mechanical* loading.

Do not specify steels of unknown weldability characteristics, and if special steels are used, specify electrodes or welding rods and welding procedures that are known to be suitable for such steels.

Complete Drawings Necessary

Provide full and definite information about all welding by means of adequate symbols such as the Standard A. W. S. Symbols (and notes where necessary), referring to standards or special types of welds and to workmanship specifications for making them.

The design drawings for a welded structure must convey all the information ordinarily required for making estimates and working drawings and they must also clearly indicate the type of connections required. For example, they must show whether beam connections are to be rigid or flexible and whether butt or lap joints are to be used.

The detail or shop drawings must show the size, shape, length and location of all welds required in the shop fabrication of the structural members and their assemblies. Separate drawings must be made to show the details of the field connections of a welded structure because they are not directly apparent from the general erection plan and the assembly of the joints. Ordinarily these drawings are made as general details of each joint and are used in ordering material and in the preparation of the shop drawings, as well as for their ultimate service in the erection of the structure.

All information regarding the details and location of welds should be given by means of the AMERICAN WELDING SOCIETY'S Standard Symbols for Welds. The universal use of these symbols will insure easy reading of the drawings and will aid considerably in reducing the mistakes and misunderstanding which must occur when welds are not systematically detailed.

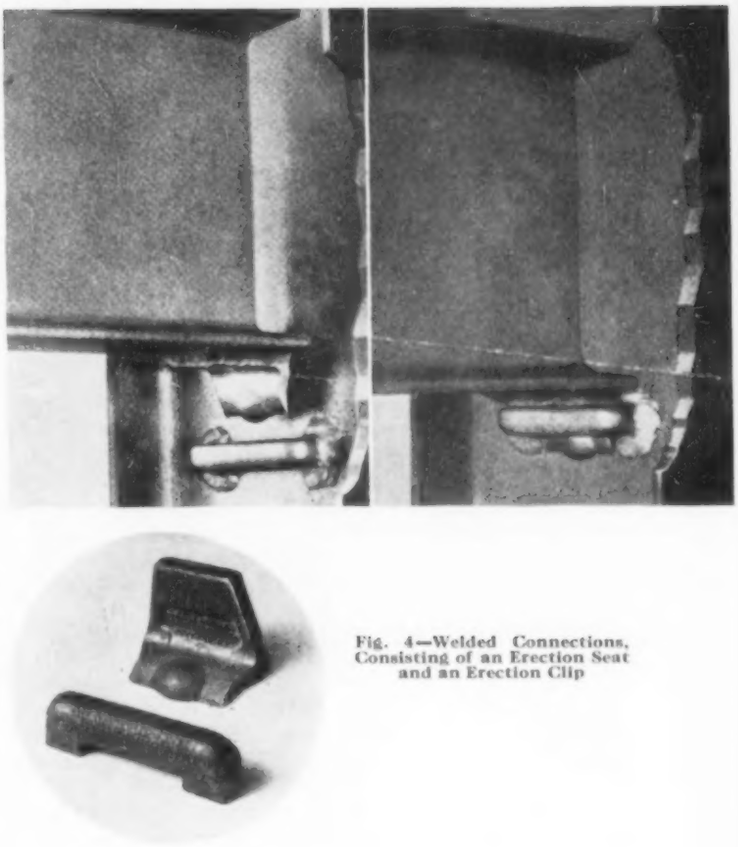


Fig. 4—Welded Connections, Consisting of an Erection Seat and an Erection Clip

Take advantage wherever possible of the natural adaptability of welding to continuous and rigid frame types of construction in which rigid joints are required (Fig. 1). Remarkable savings in cost can often be realized with this type of welded construction.

The chief difference in design between welded and riveted construction lies in the details of the connections. Welded joints are more rigid and require special study to avoid harmful effects which might follow from this condition.

Unfortunately the application to building frames of methods of analyzing continuous structures is exceedingly laborious.

Let simplicity of detail be the keynote of design. The most simple welded detail is usually the best technically and the most economical. (Note that welded girders are usually composed simply of two flange plates and a web plate, with bar stiffeners where required (Fig. 2).)

A cardinal aim should be simplicity in the details. Study spent on the details before a job goes to the shop can effect worth-while savings in cost of welded construction.

Whenever simply supported beams or girders are involved (as in tier buildings without windbracing), make definite provisions for sufficient flexibility of connections, such as is afforded by standard riveted connections, to permit end rotation of beams that must accompany simple beam deflection. In such cases the welds must be proportioned strong enough to insure deformation in the base metal.

It is probably safe to say that beam connections have been the most difficult problem confronting the engineer in the design of welded structures. The problem is not yet settled, but enough study and actual practice are available to point to safe construction methods.

The function of a beam connection is to transfer the end reaction or shear to the supporting member, be it a column, plate girder or another member.

In welded splices and connections, investigate stresses in both the welds and the base metal to determine the critical section, as in riveted work.

Early attempts at designing welded members consisted mainly in straight substitution of welds for rivets. This was not satisfactory, practically or economically. A fresh approach to the subject has developed better methods.

Size of Weld

Do not use larger welds than required from stress considerations or from stipulations as to minimum size. This is not only wasteful but in many cases it may introduce undesirable shrinkage with consequent distortion or residual stresses. Also avoid large unnecessary concentrations of welding at one point; e.g., clip the inner corners of bar stiffeners for girder webs so that the welds joining the stiffeners to the girder will not extend to and intersect the web-to-flange welds.

In designing welded structures, the welding should develop the stresses, not the material; that is, the stress should dictate the size of the welds.

Riveted work has developed its methods and practices from its own inherent nature. Welding has its own peculiarities, and should logically establish practices that are in line with these peculiarities. It is not just a matter of copying riveting practices. This leads us to the question: How much metal is in a fillet weld?

In the case of the fillet weld, an engineer will calculate the amount of welding required to develop full strength in a particular joint. After making these determinations, the size of the weld is often increased. After having been checked by the designer, inspector and foreman and fabricated by the welder, that fillet weld that was calculated to be $^3/_{16}$ inch in size has grown to a $^3/_8$-inch fillet, a weld that is much too strong and much too expensive (Fig. 3).

While the size of the weld has only been doubled, there is actually four times as much weld metal in the deposit. Consequently, the welding costs are at least four times as great as were necessary for the job.

Remember that small-size fillet welds provide more effective cross-sectional area per unit volume and cost of weld metal than larger sizes. Smaller size continuous welds are better and more efficient than larger size intermittent welds. A choice may be made. The $^5/_{16}$-inch fillet is most common because it is the largest permitted by most structural specifications to be deposited in a single pass.

In general it may be stated that fillet welds of less than $^1/_4$-inch size are not ordinarily used except along edges of plates or flanges less than $^1/_4$-inch thick. The length of a fillet subject to longitudinal stress should generally be at least four times the weld size.

The designer should avoid eccentricities in connections as much as possible and take into consideration any appreciable ones that exist even though they may be customarily neglected in standard riveted connections; e.g., eccentricities are not neglected in welded beam connection-angles or tees, in computing the welds joining the connecting material to the web of the beam.

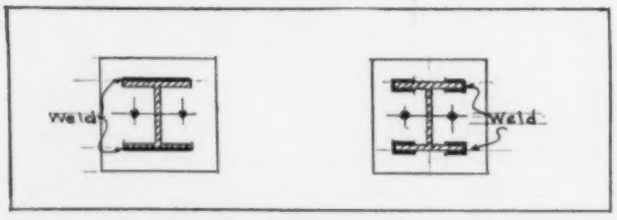


Fig. 5—Base Plates Welded to Columns

The stress on the weld of an eccentric connection is a combination of the vertical and horizontal components. The problem is simplified by treating only the linear dimension of the weld and then using a stress per linear inch, instead of per square inch.

Avoid so-called "notch effects" that induce concentrations of stress. Arrange details so as to avoid abrupt changes in contour or section that would interfere with smooth paths of stress flow; e.g., in a welded girder with no rivet holes in the flanges that would constitute "stress-raisers" and interruptions of lines of stress, it is best practice, especially for bridges, crane girders, runways and other dynamically loaded girders or beams, to avoid transverse fillet welds across tension flanges at points of high stress, and to weld ends of bar stiffeners to small fills or pads inserted with a tight fit between the flanges and the ends of the stiffeners after the girder has been otherwise completely welded. Also avoid so-called "reinforcement" of butt welds. Make their surfaces only sufficiently convex to insure full cross section equal to that of base metal.

Butt Weld Splices

Use butt-welded splices in preference to fillet-welded strap splices for dynamically loaded members. Butt welds offer better resistance to repeated stress and shock because they transfer stresses more smoothly. But be sure that a sequence of welding is adopted that will provide for contraction during welding without creating distortion or excessive shrinkage stresses. This is particularly important for members welded into rigid assemblies and for splicing wide plates or sections other than rectangular in shape.

Where the type of joint has no influence upon the size of main material, fillet-welded lap joints are likely to be more economical because they permit making allowance for mill tolerances more easily and the expense of cutting to exact length and of accurate preparation of edges for butt welds is avoided.

For fillet-welded connections use a combination of transverse welds with longitudinal welds to obtain the smoothest flow of stress lines and the best stress distribution. "Box" or return fillet welds by extending them full size around adjacent corners, especially where a longitudinal fillet theoretically ends at a corner where it is not adjacent to a transverse weld and where there would be nothing to relieve the stress concentration that occurs at the end of a longitudinal fillet weld.

Avoid details that would cause *progressive* bending or rotation (that is, not inherently self-limiting) about the longitudinal axis of a fillet weld in the direction that would cause tension in the root. Also avoid details that might cause progressive tearing of fillet welds from one end toward the other, similar to the "unbuttoning" of a line of rivets in tension due to bending.

Arrange details so that the heat applied in welding will be balanced on either side of a member as much as practicable, thus relieving tendency toward distortion.

Symmetry in the location of welds and welded connections is very desirable. The heat of welding is apt to cause a certain amount of warping, and symmetry will assist many times in maintaining the parts in their original or intended position or shape. The effect of a

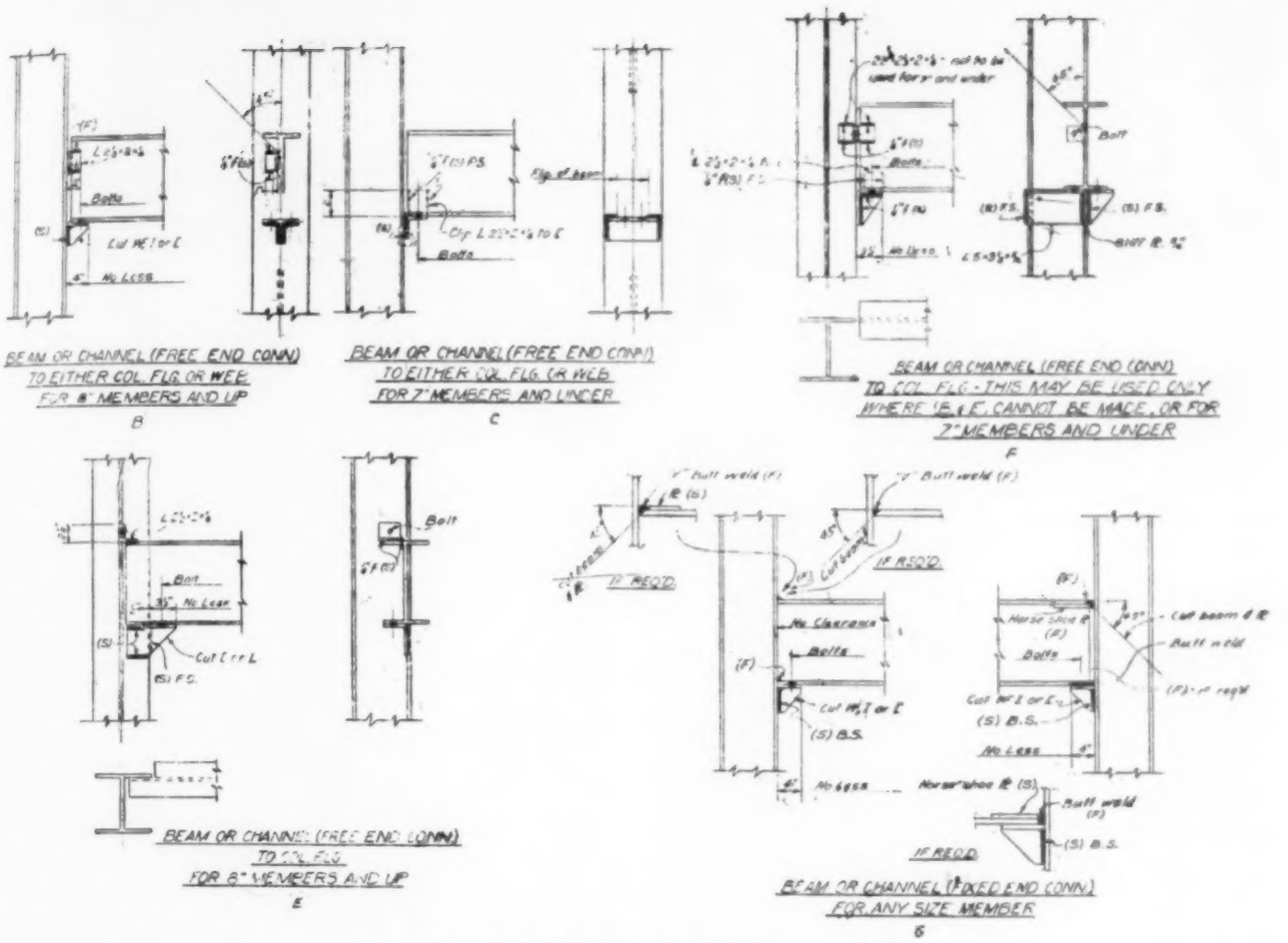

BEAM OR CHANNEL (FREE END CONN) TO EITHER COL. FLG. OR WEB FOR 8" MEMBERS AND UP
B
BEAM OR CHANNEL (FREE END CONN.) TO EITHER COL. FLG. OR WEB FOR 7" MEMBERS AND UNDER
C
BEAM OR CHANNEL (FREE END CONN.) TO COL. FLG. - THIS MAY BE USED ONLY WHERE (E & F) CANNOT BE MADE, OR FOR 7" MEMBERS AND UNDER
F
BEAM OR CHANNEL (FREE END CONN.) TO COL. FLG. FOR 8" MEMBERS AND UP
E
BEAM OR CHANNEL (FIXED END CONN.) FOR ANY SIZE MEMBER
G

Fig. 6—Showing Variety of Connections

weld on one side of a member is to cause the member to take a curved shape, concave toward the weld. This condition is often avoided in the shop by securing the parts against bending during fabrication.

Exercise care in using welds along with rivets and bolts (computed to carry stress) in the same structure. If grouped together in a new connection the rivets cannot slip to develop bearing and assure the taking of their full share of the load.

One principle of economical fabrication is to avoid, as far as possible, both welding and punching operations on the same piece of main material. This can often be accomplished by punching holes in the detail material which is welded to the larger members.

Bolted field connections for light-weight secondary beams, when permitted by the code, work out in a satisfactory manner in conjunction with welding for other field connections and for shop work. Often some cost may be saved by shop welding even though field connections are riveted. But when field welding is adopted to eliminate noise, and welding is not adopted for the shop work also, a very unfavorable combination for economy is invariably developed.

Arrange details so that they will provide easy access for performing the welding with the electrode in the correct position.

Detailed connections and joints to provide as much welding in the shop and as little in the field as possible; also so that as much of the welding as possible can be done in the down hand position.

Position for Welding

The easiest position for welding is downward. It is generally more comfortable for the welder and enables him to place the weld with greater uniformity. Vertical welding, in most cases, is quite easy to do, though not as fast as downward. Overhead welding is more difficult, both from the point of view of welding technique and from the uncomfortable position of the welder, and, furthermore, in the field will usually require some form of staging, or platform for the welder to stand on.

Provide duplication in parts or sufficient similarity for the use of jigs or fixtures wherever practicable.

Where holes must be provided to facilitate rapid erection, as for tier buildings, and some connections in industrial buildings, under conditions that prevail as to organization of erection work, detail the shop and field connections so as to necessitate punching and drilling for as few parts as possible and in as few heavy members as possible. For best economy, avoid arrangements that require both punching and welding on the same member, wherever possible. Some temporary connections, especially for bridges and industrial buildings, can be made economically with clips, cleats, lugs, etc., and held until welded, but some positive means must be provided to hold members together and align them prior to welding (Fig. 4).

No mention of costs has been made because so much depends on the shop equipment available, the location of the shop and of the job and the welding personnel.

Another factor that has a noticeable effect on welding

costs is that of drawings, both design and shop drawings.

It is common experience among fabricators to receive framing plans which indicate girders, columns, beams, etc., accompanied by such notes as these: "Girders may be welded," or "Column details are to be arc welded." Nothing definite is indicated regarding the size and the amount of welding desired. It is evident that, when the estimators price the job, they must play safe. The possible welding that might be demanded by the designer is assumed, not the amount that is actually needed. Later on, the girders or columns will be detailed with the correct welding; even if the designers accept the details as made, the cost to the owner of the structure will still be that figured into the job by the estimators.

The point made here is not that every piece should be detailed by the designer; details should be made by the detailers. But the designers should indicate clearly by notes on the drawings and by suitable items in their specifications what type of welding they will expect, what they will require for girder welding, for columns and for beams to column connections. Items recurring in considerable numbers should be plainly shown on the drawings.

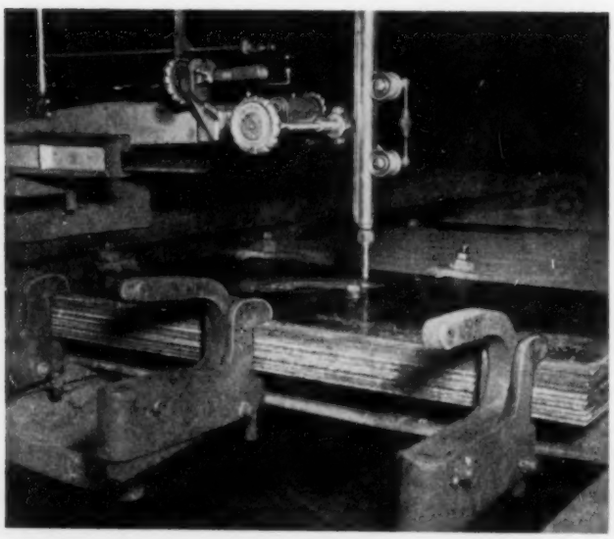
A common detail received is a column with a seat angle and the word "weld" shown. The load is not indicated; neither is the position, nor the size of fillet.

The shop may weld up both ends, or both ends and bottom or just top and bottom.

Another detail often received is a column with a base plate marked "weld."

There is usually considerable difference between the thickness of the column sections and that of the base plate. In such cases the welding requires special care. There is no good reason to weld the web to the base (Fig. 5). Even if there is bending in the column, in either direction, the welds connecting the flanges to the base would have to be torn off before an appreciable stress could be developed in the welds connecting the web to the base plate.

The fabricator's estimates are based upon your details. For they alone determine the unit costs on your job. The more exact your details, the more exact your price. The simpler the design and details, the lower the price.



These Cam-Operated Clamps of Modified Design Are Provided with Setscrews in the Lower Jaws for Additional Adjustment

Efficient Clamps for Stack-Cutting

By H. R. Gilson*

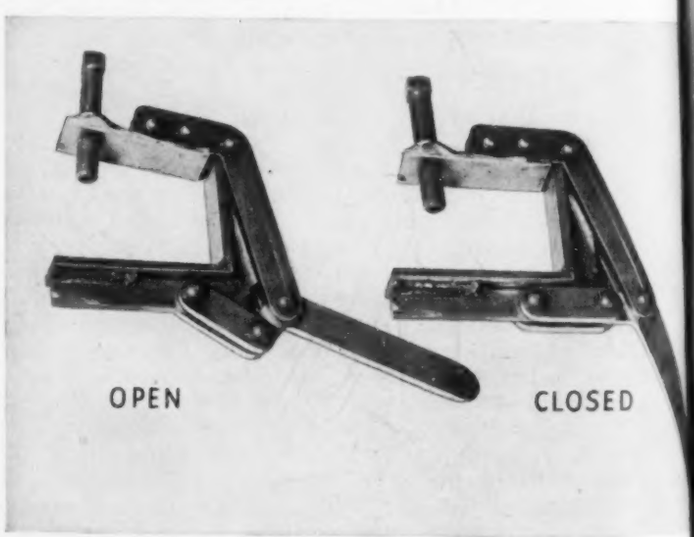
IN stack-cutting operations, accurate, high-quality results depend in large measure upon the efficiency of the clamping arrangement which holds the steel plates or sheets together. Clamps for this purpose should be of fairly simple design and should be strong enough to exert the amount of pressure necessary to hold even slightly warped plates firmly together. They should be quick-acting and easily installed, adjusted or removed as desired.

* The Linde Air Products Co., Milwaukee, Wis.

The accompanying photographs and the sketch on the following page show four variations of a type of clamp that has found rather widespread acceptance because it meets all of these requirements. Basic design is identical for all four clamps and any one of them can be fabricated by reference to the sketch which gives complete construction details. Differences exist only in the means provided for final adjustment of the space between the jaws and in the mechanism by which pressure is applied. One model is actuated by a cam and lever arrangement, a second by a screw and lever. In the other two, cam, lever and screw are combined to provide the maximum adjustment possible.

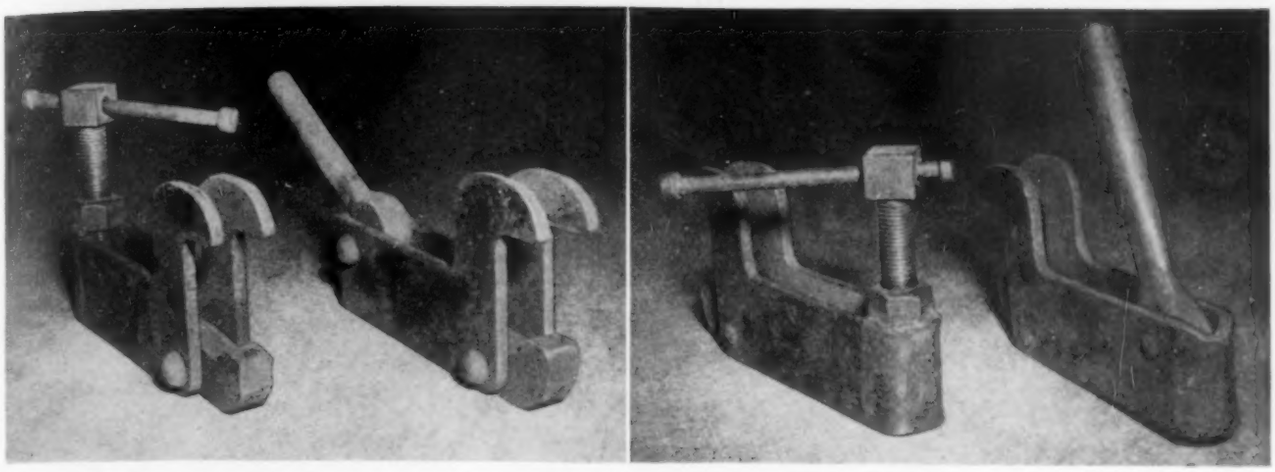
Construction and Operation

The main body of each clamp is shape-cut from $^5/_{16}$-in. steel plate, heated with the oxyacetylene flame and



Ready-Made Clamps

Stack-cutting clamps of a type similar to those discussed in the accompanying article can be purchased already made. One of these ready-made clamps is shown here in its open and closed position. It provides a clearance of $3^1/_8$ in. between its clamp jaws, and further adjustment can be made by means of a setscrew. The self-locking handle makes it easy to install and remove.

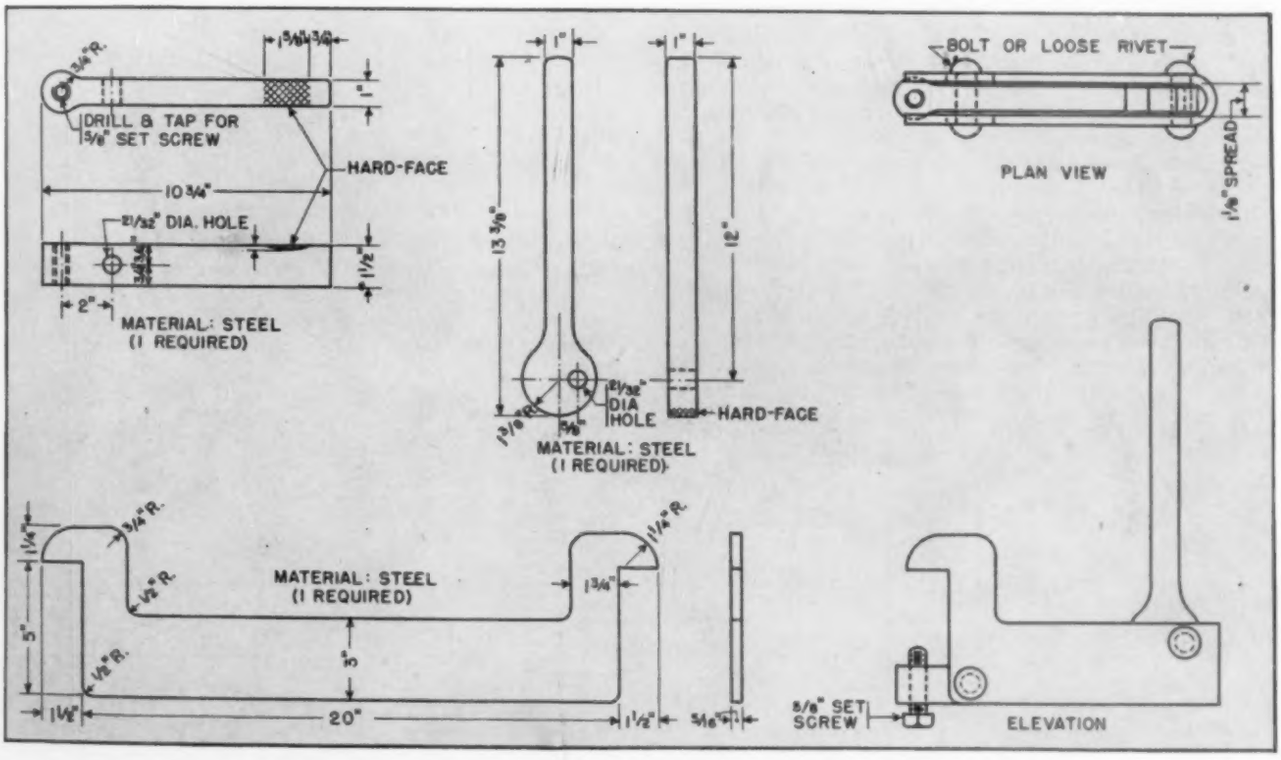


Front (Left) and Rear (Right) Views of Screw- and Cam-Operated Clamps for Stack-Cutting. Clamping Pressure Is Transmitted Through the Pivoted Lower Jaws

bent to the proper shape. The lever which serves as the lower clamp jaw is also cut from $^{5}/_{16}$-in. plate drilled to accommodate a pivot and then mounted at the forward end of the main body. At the rear, inside the bend of the main body, is added a cam or screw arrangement which bears against the end of the lever below it.

A further refinement can be obtained by tapping the lower jaw for a setscrew, as shown in the sketch. This will provide additional adjustment between the jaws. Contacting surfaces of cams, screws and levers are usually flame-hardened or hard-faced so as to provide maximum wear.

In use, the clamp jaws are positioned above and below the stack of plates. Then the handle of the cam is thrown forward or the rear actuating screw is turned down. Either of these actions exerts pressure on the rear of the pivoted lever, forcing the clamp jaws together and locking them in place. The same procedure in reverse immediately releases the clamps.



This Quick-Acting Clamp, Especially Designed for Stack-Cutting Operations, Lends Itself Readily to the Slight Variations Shown in the Photographs

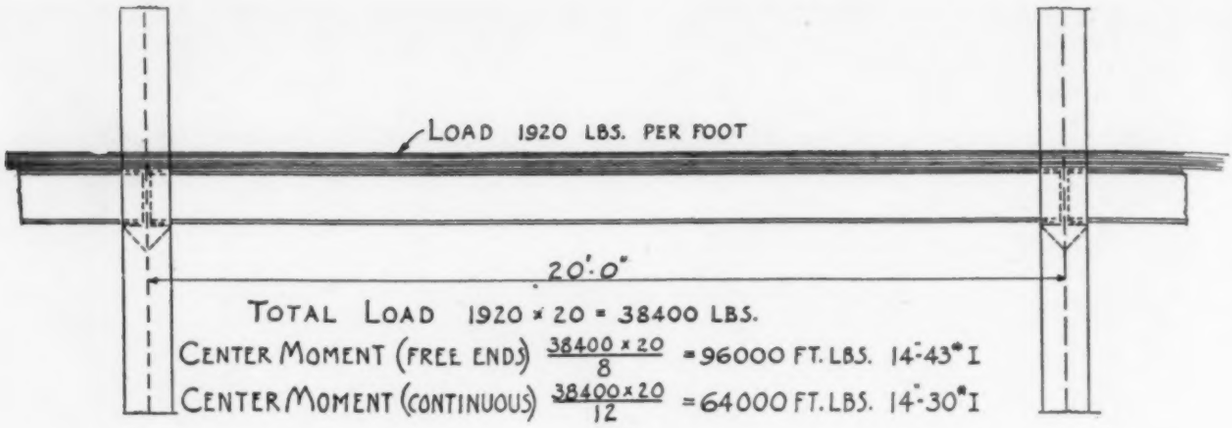

LOAD 1920 LBS. PER FOOT
20'-0"
TOTAL LOAD 1920 × 20 = 38400 LBS.
CENTER MOMENT (FREE ENDS) 38400 × 20 / 8 = 96000 FT. LBS. 14"-43" I
CENTER MOMENT (CONTINUOUS) 38400 × 20 / 12 = 64000 FT. LBS. 14"-30" I

Fig. 1

Welding Makes Continuity in Steel Work Advantageous

By G. G. Landis*

SOMETIMES reinforced concrete has an advantage over steel, when all concrete members are designed as continuous and steel members are considered as freely supported at their ends. However, arc welding furnishes a means of making steel members continuous at a cost which often makes the use of continuity in steel work advantageous.

Figure 1 shows a beam loaded with 1920 lb. per ft. on a span of 20 ft. Calculated as a freely supported beam without any continuity, the center bending moment would be 96,000 ft.-lb. Figured the way reinforced concrete would be, the center moment is 64,000 ft.-lb., requiring a 14-in. 30-lb. beam, while the 96,000 ft.-lb. above require a 14-in. 43-lb. beam, or 43% more steel.

In concrete, in order to figure the smaller moment, it is stipulated in building codes that a moment also of 64,000 ft.-lb. be developed at the beam's ends. A method of accomplishing this in steel is shown in Fig. 2. Here,

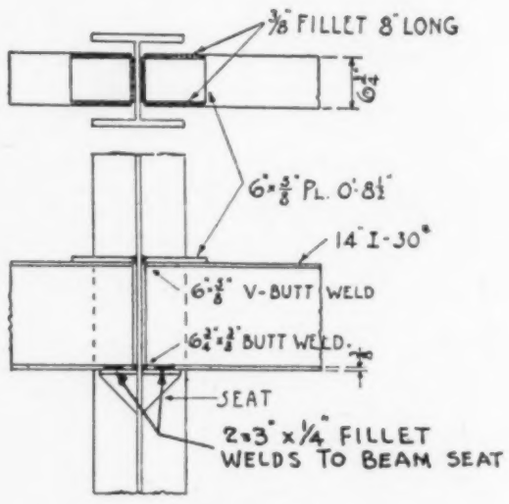


Fig. 2

an end-beveled 6-in. x 4/5-in. tie plate is field-welded to the top flange of the beam and butt welded to the column. The end of the bottom flange is butted up against the column by a 6 3/4-in. x 3/8-in. field weld between the end of the beam and the column and by two fillet welds to the seat.

The 16 inches of 3/8-in. fillet weld, as shown, have a value of (3750 × 16 × 14/12) = 70,000 ft.-lb.

The butt weld to the column has a value of (6 × 5/8 ×

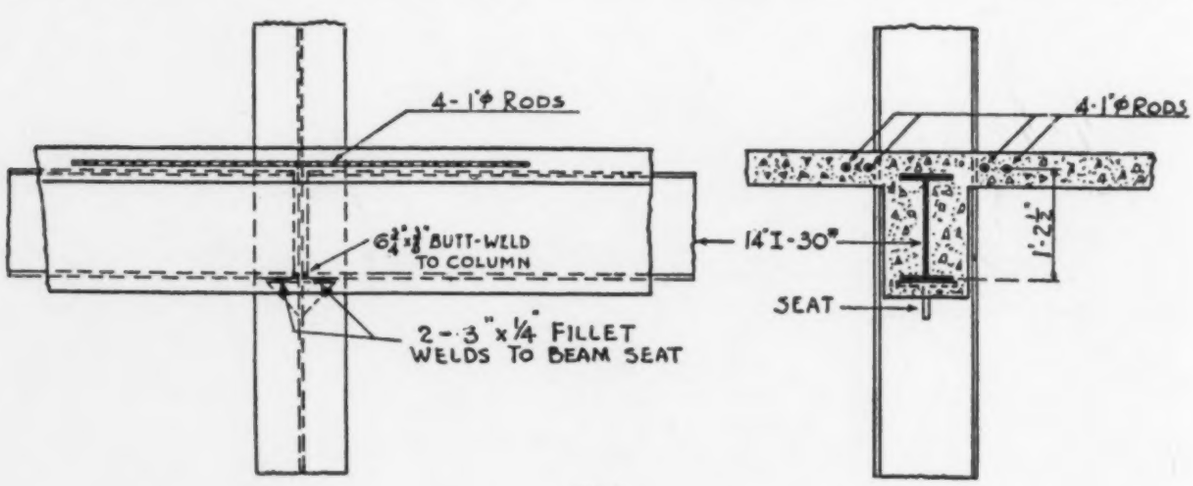


Fig. 3

* Chief Engineer, The Lincoln Electric Co., Cleveland, Ohio.

$^{14}/_{12} \times 16{,}250) = 71{,}000$ ft.-lb. The value of the $^{3}/_{8}$-in. butt weld at the end of the bottom flange is $18{,}750 \times 6^{3}/_{4} \times {}^{3}/_{8} \times {}^{14}/_{12} = 55{,}200$ ft.-lb., and that of the two 3-in. $\times$ $^{1}/_{4}$-in. fillets to the seat is $2\ (3 \times 2{,}500)\ {}^{14}/_{12} = 17{,}500$ ft.-lb., a total, for the bottom flange, of 72,700 ft.-lb.

Whenever reinforced concrete slabs are used as flooring in steel-frame buildings, a simple method of obtaining continuity for steel beams is that shown in Fig. 3. Since the steel beams themselves are encased in concrete at the time the slabs are poured, the steel and the concrete act as a unit, as proved by the tests made at the University of Toronto. If, therefore, the bottom flange of the steel beam is butt welded up against the column so as to resist the compression, the tension at the top may be taken across the column from one beam to the beam opposite by tension bars in the top of the concrete itself. In Fig. 3, the four 1-in. round rods have a value of $4 \times 0.7854 \times 18{,}000 \times \frac{14^{1}/_{2}}{12} = 68{,}000$ ft.-lb.

In this method, the steel is built in quite the usual fashion after which the bottom flange of the beams is butt welded to the columns. The tension rods are placed along with the concrete construction. Thus the floor beam tonnage is reduced as much as 25 to 30%.

Tempobrazing

By R. L. Briggs

TEMPOBRAZING* is a particularly timely development for it offers many possibilities of increased production and improved methods of fabrication at a moment when the need for such improvements is most acute. In many instances, it may even be the answer to the perplexing problems of substituting available materials for materials now difficult or impossible to obtain.

What Is Tempobrazing?

The process of brazing is not new. In fact, it is almost as old as the pyramids for the early Egyptians are known to have joined copper by a brazing process. Since then, there have been many important developments and improvements, especially in the methods of heating and in the physics and chemistry of solders and fluxes.

In spite of this great progress there has always been one disadvantage to brazing non-ferrous materials and that is the loss of hardness or temper that occurs in and around the joint. This loss is particularly marked in the case of brazed joints made in cold-worked copper and copper alloys. The brazing operation leaves the metal fully annealed or "dead soft" as it is called, and materially affects its physical properties.

Copper, for example, when cold worked to full hardness has a fine, uniform grain structure and develops a tensile strength of over 60,000 psi. When dead soft, however, the tensile strength drops to less than 40% of the full hard value and the grain structure becomes coarse and irregular. The pronounced change in the grain structure of copper when hard rolled and when fully annealed is shown in the photomicrographs, Figs. 1 and 2.

This physical change occurs when the metals are heated above a certain temperature, and particularly when they are heated and then allowed to cool with an appreciable time interval intervening. The effect is likely to be the same whether the metals are heated to a high temperature for a fairly short interval or to a lower temperature for a longer interval.

The temperature required to flow hard solder or brazing materials now commonly used, usually exceeds the range which, if maintained for an appreciable interval, effects a change in the grain structure of the metal in the pieces being joined. Under present methods of brazing, there is no practical way to control the tem-

* U. S. Patent No. 2,223,312.

Fig. 1—A Section of $^{1}/_{16}$-In. Hard-Rolled Copper Enlarged 200 Times to Show the Uniform Grain Structure

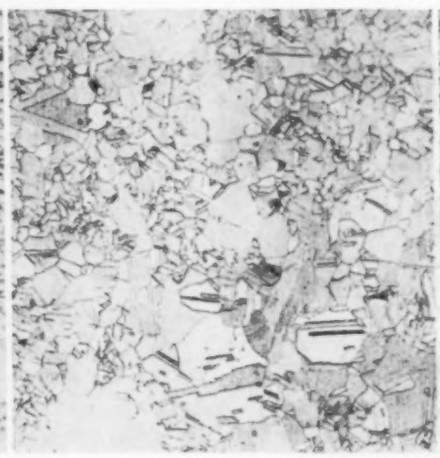


Fig. 2—A Section of $^{1}/_{16}$-In. Annealed Copper Enlarged 100 Times Showing the Coarse and Irregular Grain Structure

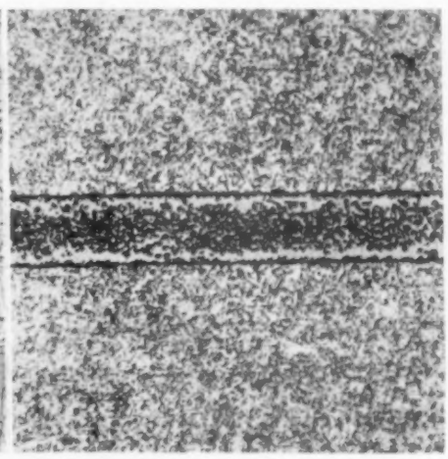


Fig. 3—A Transverse Cross Section of a Tempobrazed Lap Joint in $^{1}/_{16}$-In. Copper, Enlarged 100 Times to Show the Uniform Film of Brazing Alloy and the Fine-Grained Appearance of the Adjoining Metal

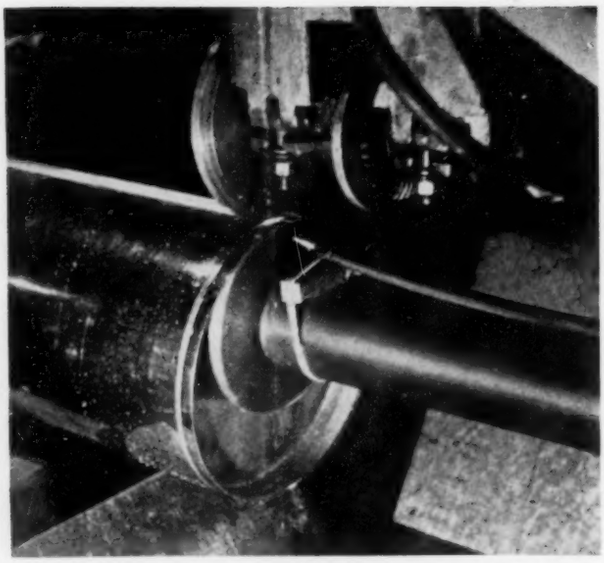


Fig. 4—Tempobrazing the Head of a Copper Hot Water Tank
The work is performed at high production speeds and the necessity for re-working the joints is eliminated.

perature and the time interval with sufficient accuracy to avoid the possibility of altering the grain structure.

Time-Temperature Control

In cooperation with Handy and Harman, Bridgeport, Conn., experts on brazing metallurgy and silver brazing alloys, we set out over six years ago to develop a method of brazing in which the time and temperature variables could be controlled to the point where grain growth is prevented and loss of hardness or temper in and around the joint avoided. This development is now complete and the process is in successful application.

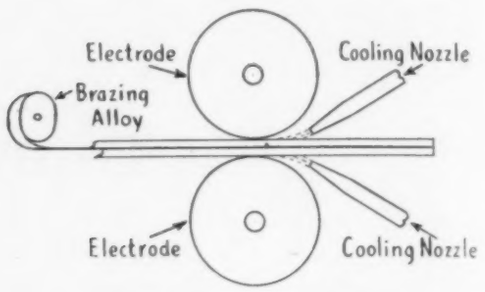
By employing accurately metered electrical energy and special solder having a flow temperature low enough to make excessive heating unnecessary, tempobrazing makes possible the accurate dual control of both the *amount* and the *time* of heat application. The operation is performed in a resistance seam welder with suitable means for inserting a silver brazing alloy between the pieces being brazed and for chilling the work as rapidly as the joint is made.

The brazing alloy used in the process is in the form of a thin ribbon as wide as the intended joint. When cooled and hardened, it forms a very thin homogeneous film, free from irregularities, voids or orifices.

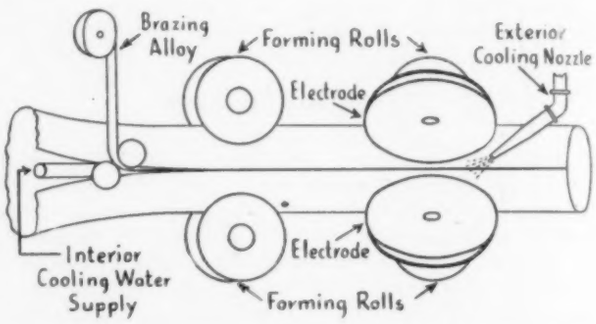
Figure 3 shows a section of a "tempobrazed" joint made in hard-rolled copper. Note the uniformity of the solder film and the fine grain appearance of the metal as compared with the structure of the annealed copper shown in Fig. 2. While not shown in the picture, the areas surrounding and immediately adjacent to the joint are absolutely unchanged in their physical structure and are all like the section shown in Fig. 1.

Applications

The process can be applied to the fabrication of articles made from non-ferrous sheet metal such as tanks, cans, boxes, boilers, continuous lengths of tubing, refrigerator parts and similar units where it is advantageous to use cold-worked materials without the necessity for re-working after the brazing operation. It cannot be applied under conditions where rapid heating and chilling is impossible or not practical and offers no advantage beyond high production if the metal is already in an annealed state or must be re-worked for some reason *not* associated with the brazing operation.



Simplified Diagram of the Operation
The brazing alloy in ribbon form is inserted before the work passes under the electrode wheels of the welder. A continuous flow of cooling water directed at the joint chills the work immediately after heat application and prevents changes in the grain structure of the metal.



A Method of Producing Continuous Lengths of Cold-Worked Copper Tubing
The work is shaped by forming rolls and brazed in one operation. Re-working of the brazed joint is unnecessary.

Figure 4 shows an example of the process applied to the manufacture of non-ferrous hot-water tanks. Ordinarily, these tanks are produced by resistance welding, in which case special alloys such as monel or several of the silicon brasses must be used, or by brazing and re-working in order to obtain the required strength. While the resistance welding method offers the advantage of high production, the special alloys required are expensive and may be difficult or impossible to obtain.

By "tempobrazing," a tank can be produced of hard-rolled copper formed into the desired shape and brazed in a resistance welding machine. There is no necessity for re-working and production is comparable to that obtained by resistance welding. Copper tanks made in this manner have physical properties that could not be obtained heretofore. They show remarkable ability to withstand "breathing" tests and have high rupture values.

IMPORTANT NOTICE: This proposed Code is being published by the Committee for the purpose of evoking comments, suggestions and criticisms. It has not been approved by the Society.

Criticisms of the Code should be submitted to M. M. Kelly, Secretary, American Welding Society, 33 West 39th Street, New York, N. Y., and must be received not later than November 1, 1941, in order to receive consideration.

Proposed

CODE OF MINIMUM REQUIREMENTS FOR INSTRUCTION OF WELDING OPERATORS

Part A—Arc Welding of Steel

FOREWORD

This Code of Minimum Requirements for Instruction of Welding Operators, Part A—Arc Welding of Steel, consists of two principal parts, namely: (1) a mandatory part, contained in Sections I to VI, all provisions and requirements of which must be fulfilled by any welding course which is to be considered as complying with this Code; and (2) a non-mandatory part, contained in Appendices A to D, which presents suggested material intended to aid welding schools in complying with the mandatory provisions.

The course of instruction prescribed herein is intended to apply primarily to persons who have had no prior experience or training as welding operators.

It is specified that the welding exercises prescribed in the Code are to be performed with covered electrodes exclusively. This provision is not to be interpreted as prohibiting or discouraging the use of bare or lightly coated electrodes for supplementary instructional purposes. Some authorities are of the opinion that preliminary instruction with bare electrodes is an effective means of accelerating the student's progress. The instructor has the privilege of using this method if he chooses to do so, but for purposes of the Code it was considered undesirable to make this practice mandatory.

In prescribing the results of the instruction (the tests which the student is required to pass before completing the course), the Code recognizes that differences in natural ability influence the degree of skill which the student is able to attain. Thus provision is made, in Article 610, whereby a student who has completed the course and is yet unable to pass the final tests in all positions, is permitted to receive a Record Card stating that he has completed the course and indicating the positions in which he has passed the tests.

SECTION I—GENERAL

101. Definition of Terms

Arc Welding: A non-pressure (fusion) welding process wherein the welding heat is obtained from an arc either between the base metal and an electrode, or between two electrodes.

Metal Arc Welding: An arc welding process wherein the electrode supplies the filler metal for the weld.

Welding Operator: An operator of welding equipment.

Other welding terms used in this Code shall be interpreted according to the American Welding Society "Definitions of Welding Terms and Master Chart of Welding Processes."

102. Scope

Part A of this Code prescribes minimum requirements for a course of instruction in manual metal arc welding, as applied to low carbon steel (0.30% carbon maximum) of thicknesses ranging from $^3/_{16}$ to $^3/_4$ in.* These requirements include principally: (1) equipment and facilities of the school, (2) qualifications of the instructor, (3) content of the instruction in welding practice, (4) content of the instruction in welding theory, and (5) tests which the student shall be required to pass before completing the course. This Code is intended to apply to public vocational schools and privately owned trade schools preparing operators for other than their own use.

103. Objectives of Course

The objectives of the course shall be: (1) to train the student in the fundamental techniques of metal arc welding; (2) to give the student a thorough understanding of the proper methods of metal arc welding, as applied to low carbon steel of thicknesses ranging from $^3/_{16}$ to $^3/_4$ in.; and (3) to provide the student with an elementary knowledge of welding theory.

The course is not expected to produce an experienced operator, but rather an operator with enough skill and knowledge so that he will have immediate value to industry as a welding operator on less difficult work, and will be able, by gaining experience in industry, to progress rapidly to work of greater difficulty.

104. Selection of Students

Students selected to receive the instruction prescribed in this Code shall have the following qualifications:

(*a*) Ability to speak and read English to the extent required for comprehension of the instruction in welding theory prescribed in Section V.

* This course is intended to cover the welding of either plate or pipe or both.

(*b*) Reasonably good health and physical development.
(*c*) Normal eyesight, or eyesight corrected to normal by glasses.
(*d*) Normal hearing.
(*e*) No mental disability.
(*f*) No physical disability that precludes safe operation of welding equipment or interferes with full performance of duties in industry.
(*g*) Eligibility to meet the minimum age requirements prescribed in the State and Federal Labor Laws applicable in the state in which the instruction is conducted.

105. Trial Period of Instruction

The first 20 hours of the course shall be a trial or probationary period, during which the instructor shall observe the aptitude of the student and determine whether in the interests of all concerned the student shall continue the course.

106. Issuance of Record Card Upon Completion of Course

Upon completion of the course and fulfilment of the requirements prescribed in this Code, the student shall be granted a Record Card witnessing thereto. The Record Card shall contain a statement of the welding operator tests which the student has passed in accordance with the provisions of Art. 610. It is recommended that the Record Card also contain a statement of the duration of the course, an outline of the exercises completed, and a positive identification of the student, as by fingerprints or a photograph. A suggested form for the Record Card is shown in Appendix A.

SECTION II—EQUIPMENT AND FACILITIES OF THE SCHOOL

201. Apparatus

(*a*) *Welding Booths*

Each welding booth shall have not less than 16 sq. ft. of clear floor space. Between booths there shall be a fire-resistant, opaque partition, which need not extend the full distance from floor to ceiling, but which shall provide adequate protection to persons in neighboring booths. Screening shall be provided so that persons not in the booth are adequately protected. Walls and ceiling shall be painted or surfaced with a material which will not reflect harmful rays. Flooring shall be of a fireproof material. Each booth, or each room of booths (if the partitions between booths do not extend to the ceiling), shall be provided with forced draft ventilation adequate to prevent the accumulation of welding fumes.

Each booth shall be equipped with a welding table and other necessary jigs and fixtures to facilitate the execution of the welding exercises and tests prescribed in Section IV.

(*b*) *Arc-Welding Machines*

The school shall be equipped with at least 50% as many arc-welding machines or welding outlets as there are students in the shop class. (See Art. 203 (*a*) for actual welding time per student.) At least 50% of the welding stations shall be of the D.C. type and of not less than 200 amperes N. E. M. A. rating. The machines shall preferably be of different makes, and at least one A.C. transformer having a N. E. M. A. rating of 200 amperes or more should be available, in order that the student may acquire experience with as great a variety of welding machines as possible.

(*c*) *Electrodes*

There shall be provided an adequate supply of metal arc-welding electrodes of the types and sizes required for the exercises prescribed in Section IV. Electrodes shall conform to the A. W. S.-A. S. T. M. Tentative Specifications for Iron and Steel Arc Welding Electrodes (A. S. T. M. Serial Designation A 233–40 T).

(*d*) *Materials for Welding*

The school shall furnish an adequate supply of low carbon steel plate (0.30% carbon max.) of the sizes required for the exercises prescribed in Section IV. This material shall be free from scale, rust, paint and other defects which adversely affect welding.

(*e*) *Testing Apparatus*

The school shall possess apparatus suitable for preparing and testing the guided-bend test specimens prescribed in Article 607, or shall have facilities for having these test specimens prepared and tested elsewhere.

(*f*) *Miscellaneous*

In addition to the foregoing, the school shall provide all other apparatus and equipment necessary for the safe and proper execution of the welding exercises prescribed in Section IV.

202. Supervision

(*a*) *Duties of Instructor*

The instructor* shall be charged with the responsibility of giving the instruction in welding practice and related subjects as prescribed in Sections IV and V. His duties shall include: (1) seeing that the student acquires safe working habits; (2) demonstrating and explaining the techniques to be used in each exercise, before the exercise is attempted by the student; (3) observing the work of each student at frequent intervals and correcting improper techniques; (4) inspecting the finished welds and explaining to the student the nature and probable causes of any defects found; (5) keeping a record of the student's progress as prescribed in Article 202 (*c*); (6) prescribing additional practice for students who require it in order to keep up with the class; (7) answering the student's questions relating to the work of the course; (8) seeing that the student observes the school's safety regulations. A list of recommended safety rules for welding schools is given in Appendix B.

(*b*) *Number of Students per Instructor*

Each shop class shall be restricted to not more than 15 students per instructor, and said instructor or instructors shall be in attendance at all times.

* See Article 301.

(*c*) *Record of Student's Progress*

An accurate record shall be kept of

SECTION III—QUALIFICATIONS

(c) Record of Student's Progress

An accurate record shall be kept of each student's progress, showing: (1) the dates of his attendance at school, (2) the number of hours of welding practice, (3) the number of hours of observation of welding, (4) the number of hours of related instruction, and (5) the dates, details and results of all tests.

203. Length of Course and Hours of Instruction

(a) Length of Instruction in Welding Practice

The instruction in welding practice shall be so organized that each student shall be required to devote a minimum of 160 hours to actual welding, exclusive of time spent in witnessing demonstrations by the instructor, observing the work of other students, testing specimens and receiving related instruction.

(b) Length of Instruction in Welding Theory

A minimum of 20 hours shall be devoted to instruction in welding theory, as prescribed in Section V.

(c) Length of Welding Practice in Any One Day

The length of time spent by the student in actual welding practice in any one day shall not exceed 6 hours.

204. Reference Materials

(a) Outline of Course

At the start of the course, each student shall be given a prepared outline indicating the scope of the course, the objectives of each group of welding exercises, the tests to be required and the subjects to be covered in the related instruction.

(b) Welding Publications

The school shall have available for student use, reference materials consisting of current books, manuals, periodicals, codes and standards pertaining to welding, including the following publications:*

Code of Minimum Requirements for Instruction of Welding Operators
Safe Practices Pamphlet No. 105—Electric Welding, Pub. by National Safety Council, Chicago
Definitions of Welding Terms and Master Chart of Welding Processes
Standard Qualification Procedure
Welding Symbols and Instructions for Their Use
Standard Methods for Mechanical Testing of Welds
Recommended Procedure to Be Followed in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles
Tentative Specifications for Iron and Steel Arc-Welding Electrodes
Qualifying Welding Operators for Important Work

An annotated selected bibliography of publications relating to arc welding instruction is given in Appendix D. It is recommended that the school library contain as many as possible of these publications.

* Except where noted, this material is published by the American Welding Society.

SECTION III—QUALIFICATIONS OF INSTRUCTOR

301. General

The instruction prescribed in this Code may be given by one instructor or by two or more instructors, provided each instructor in welding practice possesses the qualifications prescribed in Article 302, and each instructor in welding theory possesses the qualifications prescribed in Article 303. In addition each instructor shall have the ability to present effective demonstrations and explanations of those portions of the course which he is to teach.

302. Qualifications of Instructor in Welding Practice

Each instructor giving any portion of the instruction prescribed in Section IV—Instruction in Welding Practice, shall possess the following qualifications:

(*a*) a minimum of four years' total experience as a welding operator or welding supervisor, at least two years of which shall have been spent as a metal arc-welding operator,

(*b*) ability to pass all of the tests prescribed for students in Sections IV and VI of this Code.

303. Qualifications of Instructor in Welding Theory

Each instructor giving any portion of the instruction prescribed in Section V—Instruction in Welding Theory, shall be familiar with the metallurgical principles involved in the welding of steel, and shall have a thorough knowledge of the subjects covered in Section V.

SECTION IV—INSTRUCTION IN WELDING PRACTICE

401. General

Instruction in welding practice shall be given by means of a series of exercises, which shall conform at least to the minimum requirements prescribed in this Section. For the execution of any exercise the student shall have a welding booth and a welding machine for his exclusive use. After completing each group of exercises the student shall be required to pass certain check tests designed to demonstrate whether he has acquired a satisfactory degree of skill in the techniques covered by that group of exercises. The student shall be required to complete the exercises in each group and pass the required check tests, before advancing to the next group.

402. Exercises—Group A—Welding in the Flat Position

The exercises in Group A shall be designed to instruct the student in the technique of making bead, fillet and groove welds in the flat position, using electrodes of the E6010 and E6020 classifications.* All of the exercises shall be performed with $^1/_8$-in. or larger electrodes, leading to the use of $^3/_{16}$-in. E6010 electrodes and $^1/_4$-in. E6020 electrodes for the check tests.

* Electrode classification numbers used in this Code refer to the A. W. S.-A. S. T. M. Tentative Specifications for Iron & Steel Arc Welding Electrodes (A. S. T. M. Serial Designation A 233–40T).

The following exercises shall be included in this group:

(*a*) Making bead welds with E6010 and E6020 electrodes.
(*b*) Making single-pass fillet welds with E6010 and E6020 electrodes.
(*c*) Making multiple-pass fillet welds with E6010 and E6020 electrodes.
(*d*) Making groove welds with E6010 and E6020 electrodes.

Note: Detailed suggestions covering each group of exercises are given in Appendix C.

403. Check Tests on Exercises in Group A

The student shall be required to make four specimen welds conforming to the requirements stated in the following table:

Specimen Number	Joint Preparation	Position of Welding	Procedure of Welding
1	As illustrated in Fig. 1	As illustrated in Fig. 3*A*	Weld to be made in a single pass with a $^3/_{16}$-in. E6010 electrode
2	As illustrated in Fig. 1	As illustrated in Fig. 3*A*	Weld to be made in a single pass with a $^3/_{16}$-in. E6020 electrode
3	As illustrated in Fig. 2 or 2*a*	As illustrated in Fig. 3*A*	Weld to be made in multiple passes with a $^3/_{16}$-in. E6010 electrode
4	As illustrated in Fig. 2 or 2*a*	As illustrated in Fig. 3*A*	Weld to be made in multiple passes with a $^3/_{16}$-in. E6020 electrode for the root pass and a $^1/_4$-in. E6020 electrode for the succeeding passes

The welds shall be inspected visually, checked for size and contour with a gage similar to that illustrated in Fig. 4, and then ruptured as shown in Fig. 5. Each weld shall meet the following requirements:

(*a*) *Contour*—The exposed face of the weld shall be reasonably smooth and regular. There shall be no overlapping or undercutting. The weld shall conform to the required cross section for the size of weld specified, as indicated on the gage illustrated in Fig. 4.

(*b*) *Extent of Fusion*—There shall be complete fusion between the weld and base metal and full penetration to the root of the weld.

(*c*) *Soundness*—The weld shall contain no gas pocket, oxide particle or slag inclusion exceeding $^3/_{32}$ in. in greatest dimension. In addition, no square inch of weld metal area shall contain more than 6 gas pockets exceeding $^1/_{16}$ in. in greatest dimension.

404. Exercises—Group B—Welding in the Overhead Position

The exercises in Group B shall be designed to instruct the student in the technique of making bead, fillet and groove welds in the overhead position. All of the exercises shall be performed with $^1/_8$-in. or larger electrodes, leading to the use of $^3/_{16}$-in. electrodes for the check tests. The following exercises shall be included in this group:

(*a*) Making bead welds.
(*b*) Making single-pass fillet welds.
(*c*) Making multiple-pass fillet welds.
(*d*) Making groove welds.

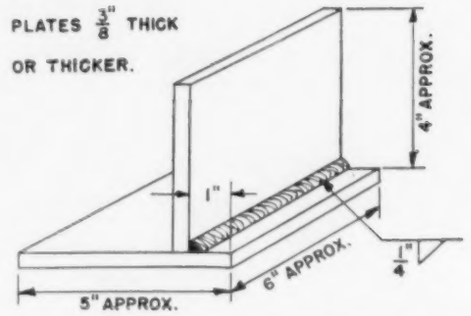


Fig. 1—Form of Joint for Fillet Weld Specimen

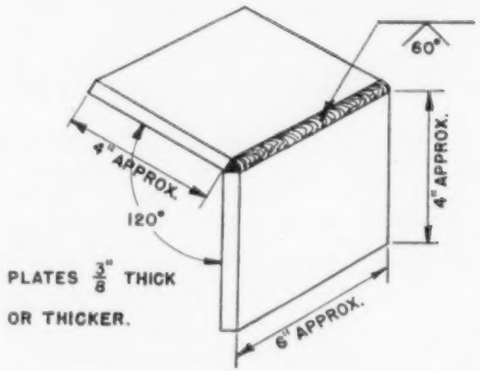


Fig. 2—Form of Joint for Groove Weld Specimen

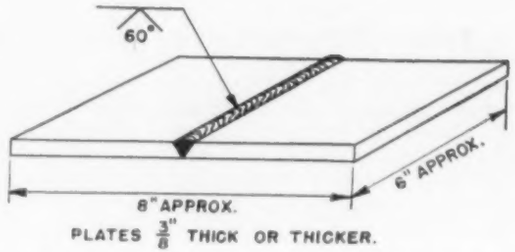


Fig. 2*a*—Alternate Form of Joint for Groove Weld Specimen

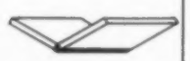
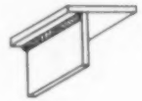
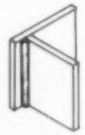
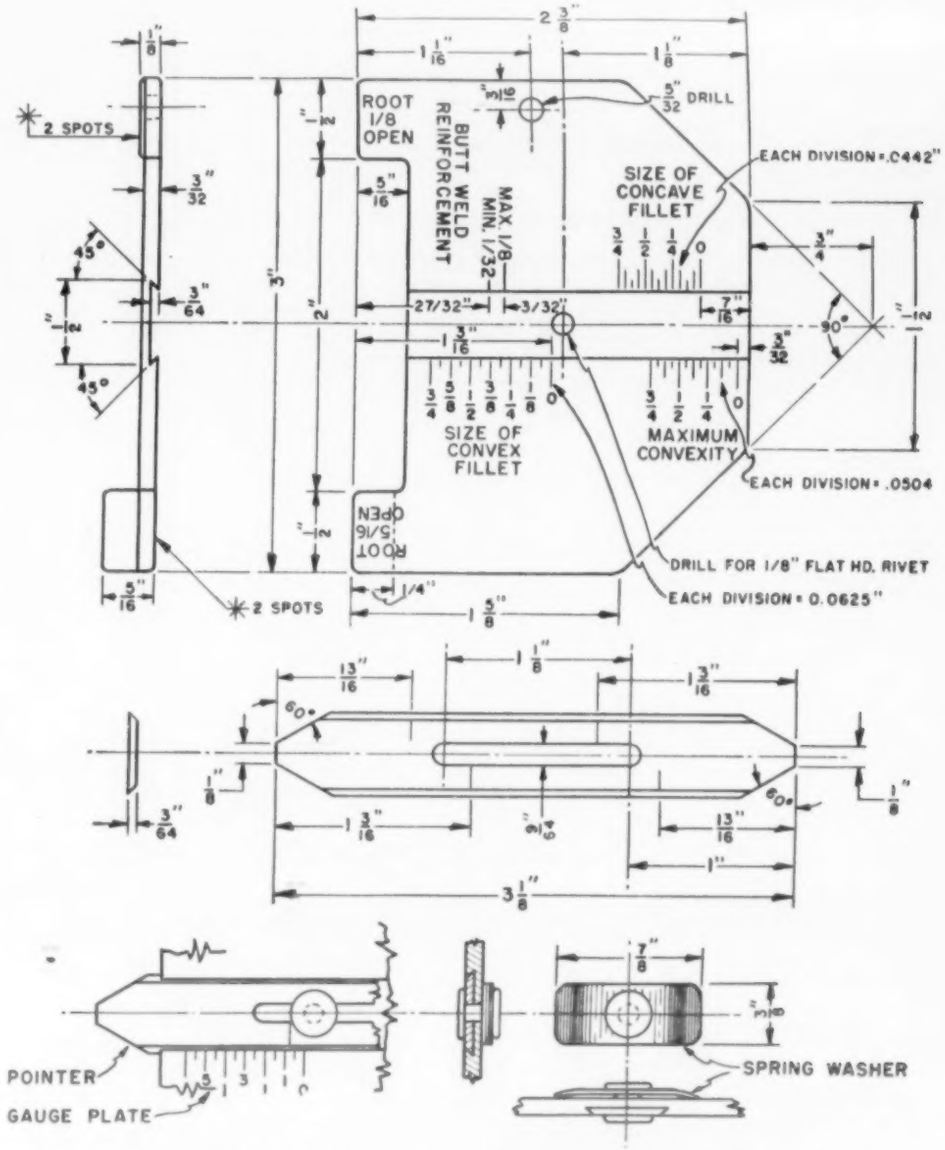
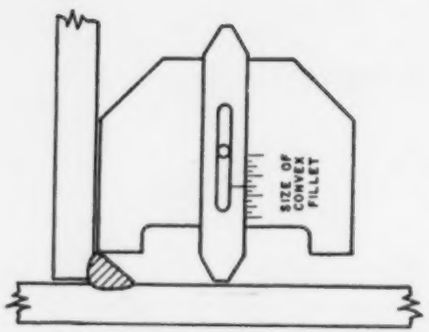
FIGURE NO.	POSITION OF WELDING	TYPE OF WELD		
		GROOVE		FILLET
3A	FLAT			
3B	OVERHEAD			
3C	VERTICAL			
3D	HORIZONTAL			

Fig. 3—Illustrations of Positions of Welding

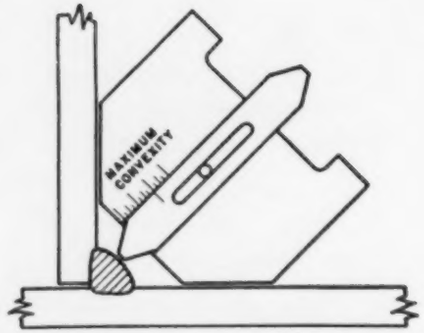


Note 1.—All parts of this gage except washer shall be made of corrosion-resistant steel. Washer shall be made of blue spring steel, cadmium plated.
Note 2.—Pointer shall be a "push fit" in gage plate and shall operate smoothly.
Note 3.—All lettering and graduations on gage shall be made by engraving.

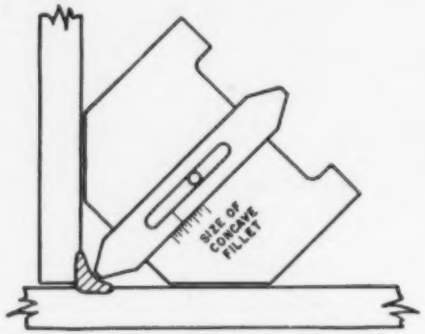
Fig. 4—Butt and Fillet Weld Gage



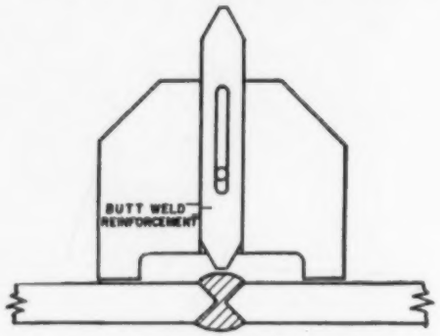
(*a*) To determine the size of a convex fillet weld, place gage against the toe of the shortest leg of the fillet and slide pointer out until it touches structure. Read "size of convex fillet" on face of gage. (See sketch above.)



(*c*) To determine the convexity of a convex fillet weld after its size has been determined, place gage against structure and slide pointer out until it touches the face of the fillet weld. The maximum convexity should not be greater than indicated by "maximum convexity" for the size of fillet being checked. (See sketch above.)



(*b*) To determine the size of a concave fillet weld, place gage against structure and slide pointer out until it touches the face of the fillet weld. Read "size of concave fillet," on face of gage. (See sketch above.)



(*d*) To determine the reinforcement of a butt weld, place gage so that reinforcement will come between legs of gage and slide pointer out until it touches the face of the weld. The permissible reinforcement is that indicated on the face of the gage. (See sketch above.)

Fig. 4*a*—Method of Using Butt and Fillet Weld Gage

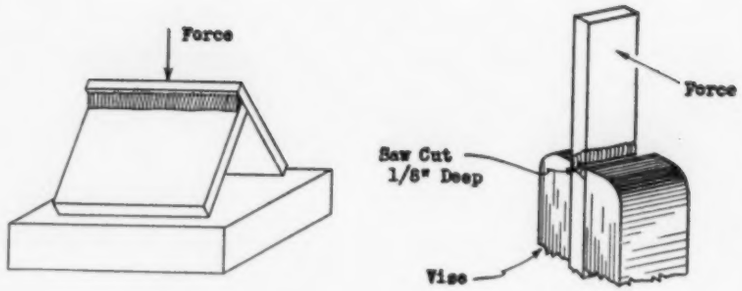


Fig. 5—Method of Rupturing Check Test Specimens

405. Check Tests on Exercises in Group B

The student shall be required to make two specimen welds conforming to the requirements stated in the following table:

Specimen Number	Joint Preparation	Position of Welding	Procedure of Welding
5	As illustrated in Fig. 1	As illustrated in Fig. 3*B*	Weld as specified in Fig. 1 to be made in a single pass with a $^{5}/_{16}$-in. E6010 electrode. After visual inspection and gaging, weld shall be increased in size by one or more additional passes to form a $^{3}/_{8}$-in. fillet weld
6	As illustrated in Fig. 2 or 2*a*	As illustrated in Fig. 3*B*	Weld to be made in multiple passes with a $^{5}/_{16}$-in. E6010 electrode

The welds shall be inspected visually, checked for size and contour with a gage similar to that illustrated in Fig. 4, and then ruptured as shown in Fig. 5. Each weld shall meet the requirements for contour, extent of fusion and soundness specified in Article 403.

406. Exercises—Group C—Welding in the Vertical Position

The exercises in Group C shall be designed to instruct the student in the technique of making bead, fillet and groove welds in the vertical position. All of the exercises shall be performed with $^{1}/_{8}$-in. or larger electrodes, leading to the use of $^{5}/_{16}$-in. electrodes for the check tests. The following exercises shall be included in this group:

(*a*) Making bead welds.
(*b*) Making single-pass fillet welds.
(*c*) Making multiple-pass fillet welds.
(*d*) Making groove welds.

407. Check Tests on Exercises in Group C

The student shall be required to make two specimen welds conforming to the requirements stated in the following table:

Specimen Number	Joint Preparation	Position of Welding	Procedure of Welding
7	As illustrated in Fig. 1	As illustrated in Fig. 3*C*	Weld as specified in Fig. 1 to be made in a single pass with a $^3/_{16}$-in. E6010 electrode. After visual inspection and gaging, weld shall be increased in size by one or more additional passes to form a $^5/_8$-in. fillet weld
8	As illustrated in Fig. 2 or 2*a*	As illustrated in Fig. 3*C*	Weld to be made in multiple passes with a $^3/_{16}$-in. E6010 electrode

The welds shall be inspected visually, checked for size and contour with a gage similar to that illustrated in Fig. 4, and then ruptured as shown in Fig. 5. Each weld shall meet the requirements for contour, extent of fusion and soundness specified in Article 403.

408. Exercises—Group D—Welding in the Horizontal Position

The exercises in this group shall be designed to instruct the student in the technique of making bead, fillet and groove welds in the horizontal position, using electrodes of the E6010 classification for the bead and groove welds and electrodes of the E6010 and E6020 classifications for the fillet welds. All of the exercises shall be performed with $^1/_8$-in. or larger electrodes, leading to the use of $^3/_{16}$-in. electrodes for the check tests. The following exercises shall be included in this group:

(*a*) Making bead welds.
(*b*) Making single-pass fillet welds.
(*c*) Making multiple-pass fillet welds.
(*d*) Making groove welds.

409. Check Tests on Exercises in Group D

The student shall be required to make three specimen welds conforming to the requirements stated in the following table:

Specimen Number	Joint Preparation	Position of Welding	Procedure of Welding
9	As illustrated in Fig. 1	As illustrated in Fig. 3*D*	Weld to be made in a single pass with a $^3/_{16}$-in. E6010 electrode
10	As illustrated in Fig. 1	As illustrated in Fig. 3*D*	Weld to be made in a single pass with a $^3/_{16}$-in. E6020 electrode
11	As illustrated in Fig. 2 or 2*a*	As illustrated in Fig. 3*D*	Weld to be made in multiple passes with a $^3/_{16}$-in. E6010 electrode

The welds shall be inspected visually, checked for size and contour with a gage similar to that illustrated in Fig. 4, and then ruptured as shown in Fig. 5. Each weld shall meet the requirements for contour, extent of fusion and soundness specified in Article 403.

SECTION V—INSTRUCTION IN WELDING THEORY

501. General

Instruction shall be given in subjects related to the theory of welding, as prescribed in the following Articles 502 to 512. Each student shall receive not less than the minimum number of hours of instruction prescribed in Article 203 (*b*). The instructor shall be responsible for seeing that each student acquires a satisfactory knowledge of the subjects covered in this Section.

502. Topic A—Safety in Welding

The instruction in this subject shall be designed to make the student aware of the necessity for observing the following safety precautions:

(*a*) Wearing proper shoes and clothing.
(*b*) Using a helmet or shield, in good condition, when in the vicinity of an electric arc.
(*c*) Providing adequate ventilation for all welding operations.
(*d*) Making provision for venting exhaust gases when operating gasoline-driven welding machines in confined spaces.
(*e*) Wearing goggles when chipping, grinding or removing slag.
(*f*) Removing combustible materials from the vicinity of welding or cutting operations.
(*g*) Taking proper precautions before welding or cutting containers which have held combustibles.*
(*h*) Striking an arc only on the work to be welded.
(*i*) Avoiding bodily contact with "live" electric circuits.
(*j*) Preventing the electrode holder from becoming grounded.
(*k*) Observing that cable connections are tight and that cables do not become hot.

It is recommended that this instruction be based on Safe Practices Pamphlet No. 105, Electric Welding, published by the National Safety Council, Inc., Chicago, Ill.

503. Topic B—Welding Machines

The instruction in this subject shall be designed to instruct the student in the care and operation of welding machines and the characteristics of machines of different types. The student shall be required to acquire at least the degree of knowledge required for the proper execution of the welding exercises prescribed in Section IV.

504. Topic C—Welding Processes and Welding Terms

The instruction in these subjects shall be designed to acquaint the student with the principal welding processes and the more important terms relating to arc welding. The instruction shall be based on the American Welding Society "Definitions of Welding Terms and Master Chart of Welding Processes."

* Refer to the American Welding Society pamphlet on "Recommended Procedure to Be Followed in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles."

505. Topic D—Weld Gages and How to Use Them

The instruction in this subject shall be designed to familiarize the student with the weld gages used in industry, and to give him a thorough knowledge of how they are applied. The student shall be afforded the opportunity of gaging actual welds with at least two types of weld gages, one of which shall be that illustrated in Fig. 4.

506. Topic E—Characteristics of Good Welds

The instruction in this subject shall be designed to familiarize the student with the characteristics of good welds. The discussion shall include the following topics: (*a*) soundness, (*b*) freedom from slag and other inclusions, (*c*) fusion between the weld and the base metal, (*d*) penetration, (*e*) sufficient size, (*f*) proper contour.

507. Topic F—Methods of Testing Welds

The instruction in this subject shall be designed to acquaint the student with the more common tests applied to welds, as described in the American Welding Society "Standard Methods for Mechanical Testing of Welds." The discussion shall include the preparation of the specimens, the testing procedure and the methods of evaluating the results.

508. Topic G—Codes, Standards and Specifications Relating to Welding

The instruction in this subject shall be designed to acquaint the student with the principal codes, standards and specifications relating to welding. Attention shall be centered upon the objectives of each standard and upon the provisions governing the qualifying of welding operators. The following publications shall be discussed:

A. S. A. Code for Pressure Piping
A. S. M. E. Unfired Pressure Vessel Code
A. S. M. E. Power Boiler Code
A. W. S. Standard Qualification Procedure
A. W. S. Code for Fusion Welding and Gas Cutting in Building Construction
A. W. S. Rules for Field Welding of Steel Storage Tanks
A. W. S. Definitions of Welding Terms and Master Chart of Welding Processes
A. W. S. Tentative Specifications for Iron and Steel Arc Welding Electrodes
A. W. S. Standard Methods for Mechanical Testing of Welds
A. W. S. Welding Symbols and Instructions for Their Use
A. W. S. Recommended Procedure to Be Followed in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles

509. Topic H—Inspection of Welds

The instruction in this subject shall be designed to acquaint the student with the more common inspection methods applied to welds. The discussion shall include a description of the following methods, together with a summary of the principal types of work to which each method is applied:

(*a*) Visual inspection and gaging.
(*b*) Leakage tests.
(*c*) Pressure tests.
(*d*) Trepanning.
(*e*) Coupon testing.
(*f*) Radiographic inspection.
(*g*) Magnaflux inspection.

510. Topic I—The Nature of Iron and Steel

The instruction in this subject shall be designed to give the student an elementary knowledge of the metallurgical factors involved in the welding of steel. The discussion shall include the chemical composition, physical properties and thermal characteristics of iron and steel.

511. Topic J—Types of Electrodes and Their Uses

The instruction in this subject shall be designed to familiarize the student with the several types of electrodes used in the metal arc welding of steel, as classified in the A. W. S.-A. S. T. M. "Tentative Specifications for Iron and Steel Arc Welding Electrodes." The discussion shall include the characteristics and uses of each classification of electrode.

512. Topic K—Welding as an Occupation

The instruction in this subject shall be designed to acquaint the student with the work of the arc-welding operator in industry. The discussion shall include the duties of the welding operator, the different types of work encountered and the qualification tests required for employment.

SECTION VI—FINAL TESTS

601. General

The final tests prescribed in this Section shall be conducted after the student has completed all the requirements prescribed in Sections IV and V of this Code. No student shall be considered as having completed the course who has not fulfilled the requirements of this Section.

602. Types of Tests Required

The tests prescribed herein are specially devised tests to determine the student's ability to produce sound welds. For fillet welds the test prescribed is the fillet-weld-soundness test; for groove welds the tests prescribed are the root- and face-bend tests.

603. Base Material and Its Preparation

The base material shall conform to A. S. T. M. Specification A7, Steel for Bridges and Buildings, or A10, Mild Steel Plates.* For each type of joint the length of the weld and the dimensions of the base material shall

* Where the student is being trained specifically for work in the shipbuilding industry, it shall be permissible to use galvanized plate for one side of the joint.

be such as to provide sufficient material for the test specimens called for hereinafter.

For groove welds the preparation of the base material for welding shall be for a single-V groove butt joint meeting the requirements of Fig. 6.

For fillet welds the preparation of the base material for welding shall be as shown in Fig. 7.

604. Position of Test Welds

For the purpose of determining the ability of the student to make welds in various positions, the positions for test shall be those illustrated in Figs. 3*A* to 3*D*, and the student shall have the privilege of taking the tests in any one or more of these positions. (See Article 610.)

If the student passes the tests in certain more difficult positions, he need not be tested in the less difficult positions but shall automatically be considered as having passed such tests, in accordance with the following provisions:

For Groove Welds—If the student passes the tests in the horizontal, vertical or overhead position, he need not be tested in the flat position.

For Fillet Welds—If the student passes the tests in the horizontal, vertical or overhead position, he need not be tested in the flat position; if he passes the tests in the vertical or overhead position he need not be tested in either the flat position or the horizontal position.

605. Number of Test Welds Required

For groove welds one test weld as shown in Fig. 6 shall be made for each position in which the student is to be tested.

For fillet welds one test weld as shown in Fig. 7 shall be made for each position in which the student is to be tested.

606. Welding Procedure

The test welds shall be made by the D.C. metal arc process using $^{3}/_{16}$-in. electrodes conforming to Classification E6010 of the A. W. S.-A. S. T. M. Tentative Specifications for Iron and Steel Arc Welding Electrodes.

607. Test Specimens—Number, Type and Preparation

(*a*) *Groove Welds*

From the finished test weld, one root-bend specimen and one face-bend specimen shall be prepared as shown in Fig. 8.

(*b*) *Fillet Welds*

From the finished test weld, two fillet-weld-soundness specimens shall be prepared as shown in Fig. 9.

608. Method of Testing Specimens

Each specimen shall be bent in a jig having the contour shown in Fig. 10, and otherwise substantially in accordance with that figure. Any convenient means may be used for moving the male member with relation to the female member.

it shall be permissible to use galvanized plate for one side of the joint.

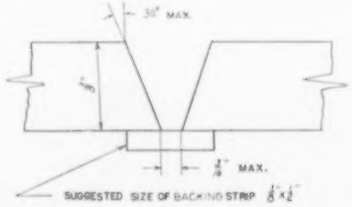


Fig. 6—Joint for Final Groove Weld Tests

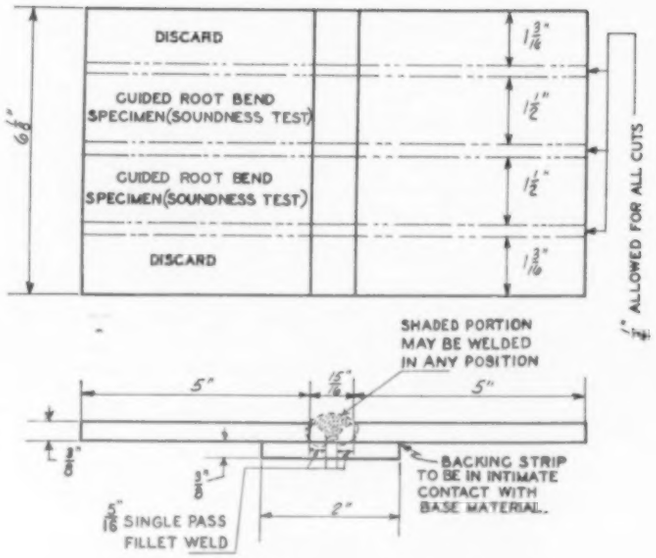


Fig. 7—Joint for Final Fillet Weld Tests

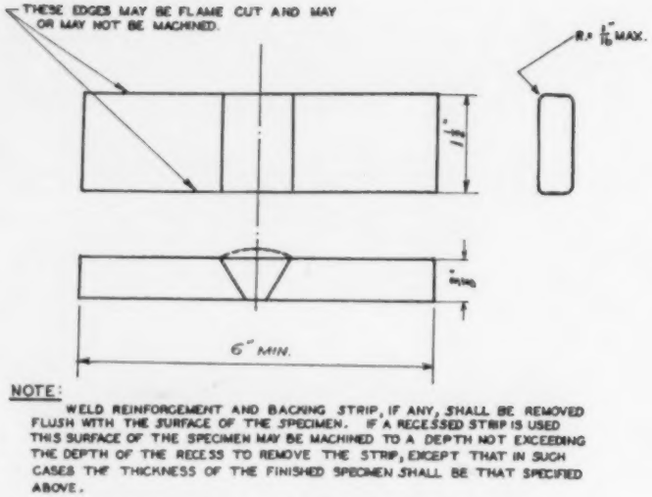

THESE EDGES MAY BE FLAME CUT AND MAY OR MAY NOT BE MACHINED.
R = 1/16" MAX.
1"
3/16"
6" MIN.
NOTE:
WELD REINFORCEMENT AND BACKING STRIP, IF ANY, SHALL BE REMOVED FLUSH WITH THE SURFACE OF THE SPECIMEN. IF A RECESSED STRIP IS USED THIS SURFACE OF THE SPECIMEN MAY BE MACHINED TO A DEPTH NOT EXCEEDING THE DEPTH OF THE RECESS TO REMOVE THE STRIP, EXCEPT THAT IN SUCH CASES THE THICKNESS OF THE FINISHED SPECIMEN SHALL BE THAT SPECIFIED ABOVE.

Fig. 8—Face- and Root-Bend Specimens

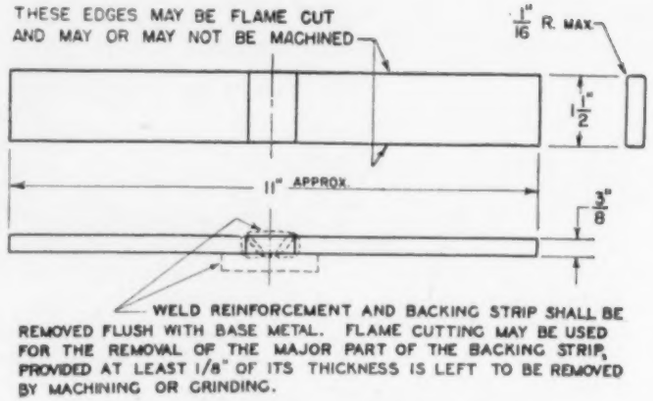

THESE EDGES MAY BE FLAME CUT AND MAY OR MAY NOT BE MACHINED
1/16" R. MAX.
1 1/2"
11" APPROX.
3/8"
WELD REINFORCEMENT AND BACKING STRIP SHALL BE REMOVED FLUSH WITH BASE METAL. FLAME CUTTING MAY BE USED FOR THE REMOVAL OF THE MAJOR PART OF THE BACKING STRIP, PROVIDED AT LEAST 1/8" OF ITS THICKNESS IS LEFT TO BE REMOVED BY MACHINING OR GRINDING.

Fig. 9—Fillet-Weld-Soundness Test Specimen

The specimen shall be placed on the female member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend and fillet-weld-soundness specimens shall be placed with the root of the weld directed toward the gap. The two members of the jig shall be forced together until the curvature of the specimen is such that a $^1/_{32}$-in. diameter wire cannot be passed between the curved portion of the male member and the specimen. The specimen shall then be removed from the jig.

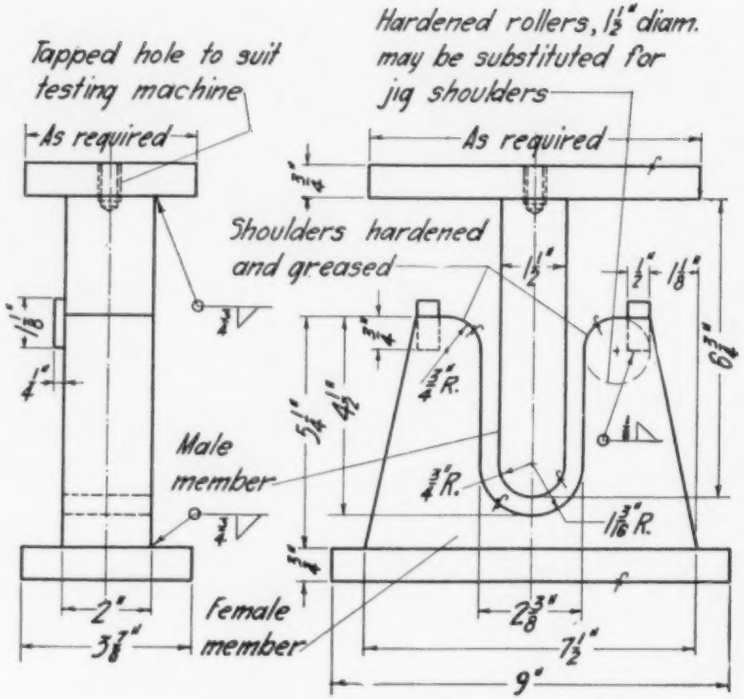


Fig. 10—Guided-Bend Test Jig

609. Evaluation of Test Results

The convex surface of the specimens shall be examined for the appearance of cracks or other open defects. Any specimen in which a crack or other open defect is present after the bending, exceeding $^1/_8$ in. measured in any direction, shall be considered as having failed. Cracks occurring on the corners of the specimen during testing shall not be considered.

610. Requirements for Passage of Final Tests

The student shall be required to pass all the tests prescribed in this Section, in at least one position. The positions in which these tests have been passed (see Article 604) shall be stated on the student's Record Card, as prescribed in Article 106.

Prepared by
Committee on Minimum Requirements of Instructions
for Welding Operators in Trade Schools

APPENDIX A — Recommended Form for Record Card

APPENDIX A Recommended Form for Record Card

Front side

(Name of School)

(City)

(State)

This Record Card certifies that

(Name of Student)

whose signature and photograph are shown on the reverse, has completed a course in arc welding conforming to the American Welding Society Code of Minimum Requirements for Instruction of Welding Operators, Part A, Arc Welding of Steel, and has fulfilled all the requirements prescribed therein. The duration of the course and the welding operator qualification tests which the student has successfully passed are stated on the reverse.

(School seal, imparting an impression in relief, to be affixed here)

By (signature of school officer)

Title (title of officer)

Date (date of issuance)

(Name of School)

Title of Course: _____

Name of Student: _____

Duration of Course:
Hours of Individual Welding Practice_____
Hours of Related Instruction_____

Type of Welding Equipment:
D. C._____
A. C._____

Results of Student's Welding Operator Qualification Tests:

Type of Weld	Position of Welding			
	Flat	Overhead	Vertical	Horizontal
Groove				
Fillet				

(Notation "passed" or "not passed" to be imprinted in each space)

Photograph of Student

Signature of Student
(Photograph and signature of student to be affixed before application of seal from reverse side.)

APPENDIX B Recommended Safety Rules for Student Arc Welding Operators

DO:

Wear leather gloves, adequate clothing and heavy shoes, tightly laced.
Wear a helmet or use a shield when in the vicinity of an electric arc.
Remove combustible materials from the vicinity of welding or gas cutting operations.
Get prompt first aid if burned or if your eyes have been injured by a flash or flying scale.
Wear safety goggles when chipping, grinding, peening or removing slag.
Keep booth and floor clean and clear of electrode stubs, scraps of metal and carelessly disposed tools.
Memorize the location of the fire extinguishers.
See that cable connections are tight and that cables do not become hot.

DON'T:

Don't look at an electric arc with the naked eye.
Don't use cracked or defective helmets or shields.
Don't pick up hot objects.
Don't use electrode holders with defective jaws.
Don't leave the electrode holder on the table or in contact with a grounded metallic surface. (Replace it on the support provided for that purpose.)
Don't weld on closed containers or on containers that have held combustible materials. (Secure permission from the instructor before welding on *any* container.)
Don't weld on galvanized metal without permission from the instructor. (Special care must be taken to provide adequate ventilation.)
Don't attempt to repair equipment.

APPENDIX C
Suggested Welding Exercises

NOTE: In the following list of suggested welding exercises, no specific recommendations are made with respect to the number of times each exercise should be repeated. The student should be required to perform each exercise to the satisfaction of the instructor, before being allowed to advance to the next exercise.

GROUP A—FLAT POSITION

Exercise No.	Operation	Plate Thickness, In.	Electrode Classification No.	Electrode Size, In.	Instructions
A-1	Striking the arc	3/16 or 1/4	E6010	1/8 or 5/32	Practice striking the arc by both methods (see Fig. C-1) until the arc can be established at any desired point
A-2	Depositing short beads without weaving	3/16 or 1/4	E6010	1/8 or 5/32	Practice depositing short beads (4 in. to 6 in.) by advancing from left to right. Then deposit beads from right to left and in a direction toward and away from the operator (see Fig. C-2). Try to obtain uniform appearance and width of bead
A-3	Depositing continuous beads without weaving	3/16 or 1/4	E6010	1/8 and 5/32	Practice restriking the arc to continue the deposition of a bead (see Fig. C-3) until it is possible to make a uniform continuous bead with craters properly filled and without excessive deposits of metal at the points of restarting the arc. Then practice making long continuous beads deposited in all directions (see Fig. C-4)
A-4	Weaving	3/16 or 1/4	E6010	1/8 and 5/32	Practice 3 or 4 different weaving techniques (see Fig. C-5), advancing from left to right and depositing a bead approximately 1/2 in. wide. Try to obtain uniform appearance and width of bead. After proficiency is attained, practice making weaving beads in a direction toward and away from the operator

GROUP A—FLAT POSITION—(*Continued*)

Exercise No.	Operation	Plate Thickness, In.	Electrode Classification No.	Electrode Size, In.	Instructions
A-5	Making single-pass fillet weld	1/4 or 3/8	E6010	5/32	Weld the joint* with a 1/4-in. fillet weld, adjusting the rate of advance so that the weld is of the proper size. Take special care to prevent undercutting, overlapping and incomplete fusion. After joint is completed, fracture the weld (see Fig. 5) and examine for slag, lack of fusion and porosity
A-6	Making single-V groove weld	3/8	E6010	5/32	Weld the joint† in 4 layers, using a weaving technique for the upper layers. Try to get complete fusion at the root of the joint. Remove the slag completely from the surface of each layer before the next layer is deposited. Take care to avoid slag inclusions and incomplete fusion at the edges of the layers. After joint is completed, fracture the weld (see Fig. 5) and examine for slag, lack of fusion and porosity
A-7	Making multiple-pass fillet weld	1/4 or 3/8	E6010	5/32	Weld the joint* with a 3/8-in. fillet weld, building up the weld in 3 passes (see Fig. C-6). After joint is completed, fracture the weld (see Fig. 5) and examine for slag, lack of fusion and porosity
A-8	Depositing beads with heavy slag type electrodes	1/4 or 3/8	E6020	3/16	Practice depositing beads both with and without weaving. Note the differences in technique required, as compared to welding with E6010 electrodes
A-9	Making fillet and groove welds with heavy slag type electrodes	3/8	E6020	3/16 and 1/4	Follow instructions for exercises A-5 and A-6

* Use form of joint shown in Fig. 1.
† Use form of joint shown in Fig. 2 or 2*a*.

GROUP A—FLAT POSITION—(*Continued*)

Fig. C-1

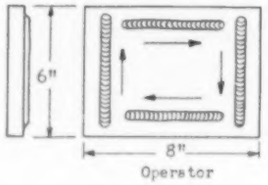


Fig. C-2

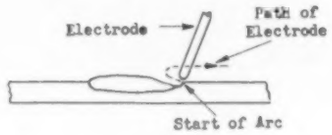


Fig. C-3

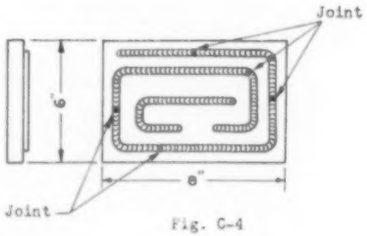


Fig. C-4

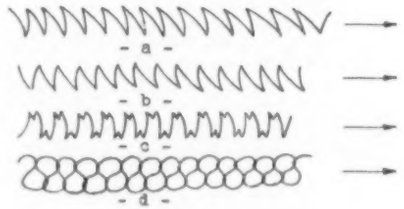


Fig. C-5

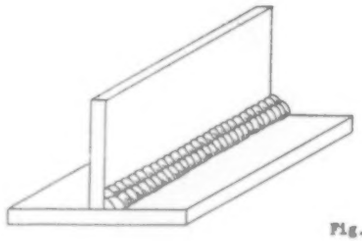


Fig. C-6

† Use form of joint shown in Fig. 2 or 2a.

GROUP A—FLAT POSITION—(*Continued*)

Exercise No.	Operation	Plate Thickness, In.	Electrode Classification No.	Electrode Size, In.	Instructions
A-10	Making check test specimen No. 1	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 403
A-11	Making check test specimen No. 2	3/8 or heavier	E6020	3/16	Follow applicable instructions prescribed in Article 403
A-12	Making check test specimen No. 3	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 403
A-13	Making check test specimen No. 4	3/8 or heavier	E6020	3/16 and 1/4	Follow applicable instructions prescribed in Article 403

GROUP B—OVERHEAD POSITION

B-1	Striking the arc	3/16 or 1/4	E6010	1/8 or 5/32	Practice striking the arc overhead until it can be easily struck and maintained
B-2	Depositing beads	3/16 or 1/4	E6010	1/8 or 5/32	Practice depositing short beads, holding a short arc and advancing from left to right without weaving. Try to obtain uniform appearance and size of bead. Then practice depositing beads from right to left. After proficiency is attained, repeat the exercises with a weaving technique, using a crescent-shaped motion and weaving about 1/4 in.
B-3	Making single-pass fillet weld	1/4 or 3/8	E6010	5/32	Follow instructions for exercise A-5
B-4	Making single-V groove weld	3/8	E6010	5/32	Follow instruction for exercise A-6
B-5	Making multiple-pass fillet weld	1/4 or 3/8	E6010	5/32	Follow instructions for exercise A-7
B-6	Making check test specimen No. 5	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 405
B-7	Making check test specimen No. 6	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 405

GROUP C—VERTICAL POSITION

Exercise No.	Operation	Plate Thickness, In.	Electrode Classification No.	Electrode Size, In.	Instructions
C-1	Depositing beads	3/16 or 1/4	E6010	1/8 or 5/32	Practice depositing vertical beads, holding a short arc and advancing in an upward direction without weaving. Try to obtain uniform appearance and size of bead. After proficiency is attained, repeat the exercise using a weaving technique and depositing a bead approximately 5/8 in. wide
C-2	Making single-pass fillet weld	1/4 or 3/8	E6010	1/8 or 5/32	Follow instructions for exercise A-5
C-3	Making single-V groove weld	3/8	E6010	5/32	Weld the joint† in three layers, using a weaving technique for depositing the second and third layers. After joint is completed, fracture the weld (see Fig. 5) and examine for slag, lack of fusion and porosity
C-4	Making multiple-pass fillet weld	1/4 or 3/8	E6010	5/32	Follow instructions for exercise A-7
C-5	Making check test specimen No. 7	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 407
C-6	Making check test specimen No. 8	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 407

† Use form of joint shown in Fig. 2 or 2*a*.

GROUP D—HORIZONTAL POSITION

Exercise No.	Operation	Plate Thickness, In.	Electrode Classification No.	Electrode Size, In.	Instructions
D-1	Depositing beads	3/16 or 1/4	E6010	1/8 or 5/32	Practice depositing horizontal beads on a vertical plate, holding a short arc and advancing from left to right without weaving. Try to obtain uniform appearance and size of bead. After proficiency is attained, practice depositing beads from right to left
D-2	Making single-V groove weld	3/8	E6010	5/32	Weld the joint† by building up the weld with the required number of straight beads, deposited without weaving. After joint is completed, fracture the weld (see Fig. 5) and examine for slag, lack of fusion, and porosity
D-3	Making single-pass fillet weld	1/4 or 3/8	E6010	5/32	Follow instructions for exercise A-5
D-4	Making multiple-pass fillet weld	1/4 or 3/8	E6010	5/32	Follow instructions for exercise A-7
D-5	Making fillet welds with heavy slag type electrodes	1/4 or 3/8	E6020	3/16 and 1/4	Practice making single- and multiple-pass fillet welds. Take care to avoid having the welds deficient in size along the vertical leg. Fracture the welds (see Fig. 5) and examine for slag, lack of fusion and porosity
D-6	Making check test specimen No. 9	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 409
D-7	Making check test specimen No. 10	3/8 or heavier	E6020	3/16	Follow applicable instructions prescribed in Article 409
D-8	Making check test specimen No. 11	3/8 or heavier	E6010	3/16	Follow applicable instructions prescribed in Article 409

† Use form of joint shown in Fig. 2 or 2*a*.

APPENDIX D

Annotated Selected Bibliography of Publications Relating to Arc Welding Instruction

FOREWORD

1. This annotated selected bibliography of reference material has been listed so that suitable material may be selected to suit the needs of student welding operators and instructors in shop and related theory instruction in the arc welding of steel. It is intended to supplement the welding exercises and other information contained in preceding appendices of this Code. Only that material which is now available and in accord with more recent technical developments is listed. The large number of fine British publications in this field have been left out as their availability is doubtful under present world conditions.

2. No attempt has been made to evaluate the reference material for instructional purposes nor to indicate a preference for the text material of any particular publisher or company.

3. In most instances the price given on publications listed does not include postage charges and State sales tax where such tax is levied. Since the price and date of publications often change with each new edition, these should be checked with the publisher.

4. Special industrial publications, other than those listed, describing arc-welding equipment, supplies, electrodes and applications may often be obtained from manufacturers of iron and steel products, welding equipment, welding supplies and electrodes.

5. The publications listed are grouped roughly into sections or parts but many of them contain information pertaining to all these groupings.

6. A key to the abbreviations used in the bibliography is given at the end of this Appendix.

PART I—SHOP WORK MANUALS AND JOB LESSON SHEETS

NOTE: The instruction or shop work manuals here listed are usually furnished by manufacturers of arc welding machines as a part of the kit of accessories.

In order that the student welding operator may become familiar with the principles and operating characteristics of various makes of welding machines, work manuals of several welding equipment manufacturers should be available to him. The course of study recommended in these manuals is usually intended for a more comprehensive training course than is necessary to meet the requirements of this Code. A number of the textbooks listed in Part II also contain job lesson sheets and shop training procedures.

1. Arc Welding Instruction Course (Exercises) 1940, AIRCo, 101 pp. **$1.00**

A course of thirty fundamental exercises (work sheets) to provide welding practice for the student so that he may become acquainted with the correct technique for application and manipulation of various types of electrodes, as well as the procedure and method of making different types of welds. Exercises are provided in the use of both bare and coated electrodes. A chapter is devoted to oxyacetylene cutting and another to carbon arc welding. Definitions of welding terms are included. Line drawings and photographs are used effectively. Materials and equipment required for each exercise are given. Simple standard tests are provided to evaluate the progress made.

2. Arc Welding Manual (No. GES-2278), 1939, GE, 204 pp. **WPFP**

This pocket-sized manual prepared for use in GE welding training programs contains general information on: machines and equipment; technique of arc welding; practical applications; automatic arc welding; atomic-hydrogen arc welding. A shop training course of 40 well-illustrated lessons for arc-welding operators is included. Appendix contains convenient tables and handy estimator for determining electrode quantities.

3. Arc Welding and How to Use It, 1938, HBCo, 334 pp. **WPFP**

A rather comprehensive arc-welding manual covering both practice and theory. It is based on practices of Hobart's welding school. Many actual photographs and line drawings are used effectively to supplement the theory. The chapter headings are: (1) General Information; (2) Practical Welding Lessons (97 pages); (3) Carbon Arc Welding and Cutting; (4) Instructions for Welding Other Metals; (5) Special Information. Parts (2) and (3) are also available at a small cost, each enclosed in its own paper binder.

4. 41 Lessons in Arc Welding (Instruction Book 5801A), 1941, WE&MCo., 67 figures. **$.50**

A course of 41 illustrated lessons on plate welding with bare and shielded arc types of electrodes, prepared by Westinghouse engineers for use in the company's welding school. Each lesson contains a brief discussion of the theory pertinent to the lesson under consideration, a practice procedure, and a required test specimen. Lessons include fillet and groove welds, made in all positions with four types of electrodes. Revised edition published serially in *The Iron Age* magazine weekly, commencing with the issue of February 20, 1941.

5. Lessons in Arc Welding, Second Edition, 1941, LEC, 184 pp., 170 illus. **$ .50**

This is a series of sixty complete and well illustrated lessons, or shop exercises, based on the experience of Arthur Madson, instructor of the LEC Welding School, presenting in a concise and complete manner fundamental procedures and applications in arc welding. The previous edition of "Lessons in Arc Welding" has been considered by many as a standard textbook of welding exercises for welding schools. This new edition has been enlarged, completely rewritten and reillustrated. The descriptive

matter on electrodes is greatly expanded and includes AWS specification numbers. Most of the material on electrodes published in this Company's Weldirectory appears in this new book. The subject matter includes lessons on the operating principles of the arc welder, use and description of bare and heavy coated electrodes on both mild steel and alloyed metals, and special applications of the arc welding process. Most of the lessons include the object of the exercises, apparatus necessary (generally a 200 or 300 ampere welder), size of plate and size and type of electrode recommended and procedure or details of operations. It is beyond the province of most welding courses to give training on all alloy and non-ferrous electrodes. For pre-employment training on mild steel plate twenty-two of these lessons form a sound basic course. Most of the remaining lessons are so arranged to enable the instructor to develop supplementary courses. A supplement giving changes necessary to permit use of some of the lessons with smaller welding units is included. Test questions and answers on some of the lessons are given.

6. Arc Welding Manual, HC, 40 pp. WPFP

A small, concise manual for use with the Hansen arc welder. Topics discussed are instructions for operating welder; instructions to beginners (eight lessons); types and preparation of joints to be welded; arc-welding methods and applications. Well illustrated.

7. How to Weld 29 Metals, 3rd Edition, Jennings, C. H., 1940, WE&MCo., 103 pp. $ .50

This is a practical, usable treatise on arc welding, written in language understandable by welding operators. Considerable space is devoted to modern alloy-steels and non-ferrous metals. Both theory and technique are effectively presented with illustrations, charts and tables. All data are condensed to furnish maximum information with a minimum of reading. The author is in charge of welding research for WE&MCo.

8. Electric Arc Welding, 1941 CRCo., 13 pp., illus. Free

This small trade publication deals briefly with the simple and fundamental facts of arc welding and is primarily intended to promote the use of electrodes manufactured by this company. The principal topics are fundamental facts of welding and types of electrodes, including the tentative specifications of the AWS for iron and steel arc-welding electrodes. Also included are manual qualifications of arc welders, testing of welds, types of joints and some definitions of metallurgical and welding terms. Contains several fine photographs.

9. The Welding and Flame Cutting of Wrought Iron, 1941 (Byers Co.), 20 pp., 19 illus. (O&O-A) Free

A service bulletin prepared by the engineering service department of this company. Written in easily understandable technical language, well illustrated by actual photographs and 9 tables. Principal topics covered include processes and procedures of welding wrought iron, physical properties of welds including several photomicrographs, the flame cutting of wrought iron, the flame descaling of wrought iron.

PART II—RELATED TECHNICAL THEORY AND HANDBOOKS

NOTE: Instructional material of the type annotated here is intended to supplement the use of the standards, specifications and codes in Part III of this bibliography as a source of information for the related technical theory covered in Section V of this Code. This material applies more specifically to the directly related technical theory than that listed in Part IV.

1. AWS Welding Handbook, 2nd Edition, Dec. 1941, AWS (A&O-A), approximately 1200 pp. $6.00

This 1941 edition of the American Welding Society's handbook contains detailed practical and theoretical information on every phase of welding and gas cutting. Each chapter is the work of a committee comprising the country's leading authorities on the subject covered. The first part is devoted to fundamental considerations such as physics and metallurgy of welding in general, followed by a complete treatment in a fundamental way of all the major and allied processes of welding and related applications. Other chapters deal with welding of the common metals and alloys, training welding operators, inspection and safety. The volume closes with several chapters devoted to applications of welding.

2. Arc Welding Instruction Course (Lectures), 1940, AIRCo., 89 pp. $1.00

The twenty lectures included in this publication are intended for the guidance of the instructor in giving his classroom discussion on related welding theory. The first lecture on safety is followed by a discussion on elementary electrical theory as it applies to direct and alternating currents, magnetism, etc., and the application of these principles to welding generators and transformers. Chapters are included on: nature of iron and steel; electrodes, welding processes and welding symbols; arc welding classifications; operator requirements and tests. Well illustrated by 76 photographs and line drawings and 8 tables. The appendix includes a chapter on school facilities and necessary equipment.

3. Procedure Handbook of Arc Welding Design and Practice, Sixth Edition, 1940, LEC, 1152 pp., 1557 illus. $1.50

An authoritative and comprehensive reference handbook on arc welding. Contents include welding methods and equipment; technique of welding; procedures, speeds and costs of welding mild steel; weld metal and methods of testing; weldability of metals; construction of machinery; designing of arc-welded structures; typical applications of arc welding in manufacturing, construction and maintenance. Contains many charts, diagrams, specifications and a plan of a simple polariscope.

4. The Welding Encyclopedia, Tenth Edition, re-edited by Plumley, S., 1941, WEP, 712 pp. (A&O-A) $5.00

A practical reference book giving descriptive information and definitions of all welding terms, processes and their application. The alphabetical arrangement enables the reader to quickly find almost anything which he desires to know about the welding processes. Many topics,

melt welding; spot welding. A chapter is devoted to the Unionmelt proc-

including the training of welding operators and welding operator qualification tests, are treated in considerable detail. It is liberally illustrated with line drawings and photographs. Commercial products and trade names are listed together with names and addresses of the manufacturers.

5. Electric Welding, Book I, Vol. 604, Kraus, R., and Lincoln, R. B., 1937, 224 pp., 181 illus., BBS, ICS, ITBC $2.10

This is ICS home study material in textbook form on welding theory and shop welding technique. The volume treats on: electricity for welders; arc-welding equipment; arc welding of low carbon steel with bare and coated electrodes; carbon arc and atomic-hydrogen welding; automatic arc welding. Each topic is discussed in detail with effective illustrations.

6. Electric Welding, Book II, Vol. 605, Kraus, R., and Lincoln, R. B., 1938, BBS, ICS, ITBE, 258 pp., 166 illus. $2.60

This volume discusses: arc welding of alloy steels and iron; applications of arc welding; carbon-arc cutting; arc welding of non-ferrous metals and overlaying; hard-facing; resistance welding; inspection and testing of welds; scope of inspector's work; magnaflux, sonic and radiographic examination; polariscope tests; destructive tests; codes for fusion welding; protection of welding operators.

7. Arc Welding Handbook, Holslag, C. J., 1941, AWS, 313 pp. $2.00

A simple and practical manual of instruction in arc welding, describing in step-by-step manner a number of typical welding applications, e.g., padding a shaft, fillet welding of plates, butt welding of plates, welding a broken crankshaft, welding sheet, welding heavy sections. The book is intended for the beginner and also for the engineer, draftsman and designer as a guide in the use of arc welding.

8. Manual of Electric Arc Welding, Hubert, E. H., 1932, McGH, 163 pp., 126 illus. $2.00

A manual covering all phases of electric arc welding and containing much specific and practical information. Chapters treat on: the welding process, equipment for welding, expansion and contraction, definitions and types of joints, speed of welding, strength of welds, design of joints, preparation of work, making welds, welding special metals, practical welding applications, welding methods, rules and regulations, detailed outline of a training course for arc-welding operators, and engineering data and tables.

9. Electric Welding, Potter, M. H., 1938, ATS, 126 pp., 86 illus. $1.25

This book is based largely on the experiences of the author, formerly instructor of welding in a large midwest vocational school. The entire field of electric welding is briefly covered in both technical theory and practice. The language is simple and easy for the inexperienced welding operator to understand. Effective illustrations increase its value. Methods and applications of welding are treated at length.

10. Audel's Welder's Guide, Graham, F. D., 1940, TA&Co, 432 pp. (A&O-A) $1.00

A concise pocket-sized handbook written in simple question-and-answer style. The topics discussed include: theory, operation and maintenance of electric welding machines; applications of arc, gas, thermit and Unionmelt welding; spot welding. A chapter is devoted to the Unionmelt process. Not indexed.

11. Health Protection of Welders, MLICo, 27 pp. (A&O-A) Free

A discussion of the possible hazards to the health of the welding operator from welding fumes, metal fumes and light and heat rays, with suggestions for appropriate protection. The health hazards are discussed under four headings: Electric Shock and Burns; Radiant Energy; Gases, Fumes and Dust; Miscellaneous Hazards. An illustration of an effective ventilation system is shown.

12. Simple Blueprint Reading with Special Reference to Welding, 1940, LEC, 138 pp., 164 illus. $ .50

This book forms a basis for study of blueprint reading. While it has been written primarily for welding operators, it contains information of value to anyone concerned with mechanical construction. The text is concisely written in simple, practical language. For ready understanding, many legible drawings are used. Much space is devoted to interpretation of welding symbols on drawings. Many practice drawings are provided for home study. Answers to certain questions in the reading of the drawings are given.

PART III—WELDING STANDARDS, SPECIFICATIONS AND CODES

NOTE: Article 204 (*b*) of this Code lists the welding publications each welding school must provide for student use, in order to meet the requirements of this Code. The publications listed as Nos. 2 to 9 below are in this required list. Certain additional codes which are listed in Article 508 should be available to the welding instructor. This material represents the most authoritative information available for related technical instruction of welding operators. However, standards, specifications and codes in which technical advancement is as rapid as in welding, are constantly being revised. Instructors should keep in touch with code-making bodies for latest revisions. In addition to the AWS, the American Standards Association, American Institute of Electrical Engineers, American Society for Metals, National Safety Council and others prepare material of interest to welding instructors. The material in this part is applicable to both arc and oxyacetylene welding unless specifically titled for electric arc welding.

1. Specifications for Welding, Appendix 5, Part 1—General—for Vessels of U. S. Navy, Bureau of Ships, April 1940, USSofD, 64 pp. $ .15

Although this is an official publication of the Navy Department, Bureau of Ships, it is not confidential and may be purchased from the U. S. Government Printing Office. The instructions contained in this bulletin govern all work under the cognizance of the Bureau of Ships done by contractors, navy yards, naval stations and forces afloat. Topics of particular interest to the arc-welding operator include: types of approved electrodes; welding procedures, including joint preparation, tack welding, preheat and postheat treatment, making of welds, finish, cleaning and protection of welds; piping; special alloys; gas cutting; tests and inspection; arc and

gas welding symbols and instruction for their use; drawing of butt and fillet weld gage and illustrated instruction for its use. Considerable design data for welded joints and piping are given. Well indexed. Every welding operator who expects to work in a shipyard should have a copy of this bulletin.

2. Safe Practices Pamphlet, No. 105, Electric Welding, NSC, 1941, 12 pp. (Available only to members of NSC and public vocational schools.) **$ .25**

This pamphlet is one of more than 150 Safe Practices and Health Practices pamphlets of the NSC. It includes 85 paragraphs on arc welding and 27 on resistance welding. Topics discussed include: the arc welding process; power supply; arc welding machines; cables; electrodes and electrode holders; machine welding; protection against shock and harmful light rays; personal protective equipment; health hazards and fire protection; and general precautions. The hazards involved in the above categories are discussed and specific safe practices procedures are recommended. Resistance welding is similarly treated. Effectively illustrated by 21 photographs and tables. Not indexed. The suggestions contained in this pamphlet do not conflict with other standard safety and health codes and laws applicable to electric welding. Should be included in the instructional material of every course in electric welding.

3. Welding Symbols and Instructions for Their Use, 1940, AWS, 24 pp. **$ .25**

A booklet describing the American Welding Society's standard symbols to denote arc, gas and resistance welds on engineering shop drawings. The symbol legends are fully described and detailed instructions for their use are presented. The booklet includes numerous illustrations of the application of the symbols to various types of engineering drawings.

4. Definitions of Welding Terms and Master Chart of Welding Processes, 1940, AWS, 23 pp. **$ .25**

A booklet giving the standard definitions of welding terms adopted by the American Welding Society. Fifty illustrations are included to assist in making the various definitions clear. The booklet also includes a chart showing the various subdivisions of the principal welding processes, namely, forge welding, resistance welding, arc welding, gas welding, thermit welding and brazing. Figure 1 may be subject to change at some future date.

5. Standard Qualification Procedure, AWS, 1941, 39 pp. **$ .25**

A booklet describing the Standard Qualification Procedure approved by the American Welding Society, for the use of industry and code-writing bodies wishing to prescribe methods for testing welding procedures and checking the ability of welding operators. The Standard Qualification Procedure has been incorporated in practically all of the more important codes and specifications on welding. Every welding instructor should be thoroughly familiar with this Standard.

6. Tentative Specifications for Iron and Steel Arc Welding Electrodes, 1940, AWS, 7 pp. **$ .25**

A specification giving the dimensions, characteristics and properties of 14 different classifications of lightly coated and covered metal arc welding electrodes for the welding of carbon and low-alloy steels. The specification prescribes certain properties for welds made from these electrodes. A detailed drawing showing construction of AWS Butt and Fillet Weld Gage and four sketches showing method of using are included. Figure 1 may be subject to change at some future date.

7. Standard Methods for Mechanical Testing of Welds, 1940, AWS, 24 pp. **$ .25**

A booklet describing in detail the principal mechanical tests applied to welds, including tests for density, soundness, tensile strength, shearing strength and ductility (bend tests). The booklet includes sketches of the specimens and descriptions of the methods of testing and evaluating results for mechanical testing of base metal, weld metal, butt-welded joints and fillet-welded joints. Reagents and procedures for etching are given. This is not a procedure for qualification of welding operators but a booklet describing methods of making mechanical tests applied to welds.

8. Qualifying Welding Operators for Important Work, Dalcher, L. M., 1940, AWS, 3 pp. **$ .05**

This is a general survey of the subject of welding operator qualification tests, and the qualifications required of welding operators for various types of work. A table gives the type of welding, title of code or specification and name of sponsoring organization, field of application, and source from which copy of code and further information may be obtained.

In general, it also briefly treats on code requirements, AWS Standard Qualification Procedure, inspection agencies and requirements for government employment. This material appeared in the November 1940 issue of the AWS Welding Journal and was condensed in the April 1941 issue of *Industry and Welding*.

9. Recommended Procedure to Be Followed in Preparing for Welding or Cutting Certain Types of Containers Which Have Held Combustibles, 1940, AWS, 12 pp. **$ .10**

A booklet outlining safety precautions to be taken in order to insure that explosion or fire will not result when welding, gas cutting or performing other hot work on tanks or other containers which have held combustible solids, liquids or gases.

10. Code for Fusion Welding and Gas Cutting in Building Construction, 1937, AWS, 19 pp. **$ .25**

A code prescribing rules to cover the application of arc and gas welding in building construction, intended principally for adoption by municipalities as part of their building code. The provisions of the code govern materials, design, permissible unit stress, workmanship and inspection. A new edition will be issued toward the latter part of 1941.

11. Rules for Field Welding of Steel Storage Tanks, 1940, AWS, 19 pp. **$ .25**

A booklet containing rules intended to prescribe safe welding requirements for the construction of bulk storage tanks for holding liquids at substantially atmospheric pressure. The rules cover materials, design, workmanship, inspection and testing.

12. A.S.A. Code for Pressure Piping, 1935, American Standards Association, 164 pp. **$1.00**

This code prescribes a standard of minimum

A specification giving the dimensions, characteristics and properties of

workmanship, inspection and testing.

12. A.S.A. Code for Pressure Piping, 1935, American Standards Association, 164 pp. $1.00

This code prescribes a standard of minimum safety requirements for pressure piping, with respect to materials, dimensional standards, and the design, erection and testing of piping systems. One chapter of the code is devoted to welding of pipe joints. The AWS cooperated in preparing this chapter.

13. A.S.M.E. Code for Unfired Pressure Vessels, 1940, American Society of Mechanical Engineers, 187 pp. $1.50

This code prescribes a standard of minimum safety requirements for the construction of unfired pressure vessels. Part of the code is devoted to the regulations governing the application of fusion welding and forge welding. The AWS cooperated in preparing this part of the code, which includes the current AWS Standard Qualification Procedure.

PART IV—GENERAL PUBLICATIONS DEALING WHOLLY OR IN PART WITH ARC WELDING

NOTE: The material listed in this part deals chiefly with the more elementary phases of metallurgy as related to welding, and the application of welding to ship construction and repair, metal manufacturing, and building construction. Selected text material of interest to arc-welding operators is included. This material is of a more general nature than that given in the three preceding parts and should be considered as supplementary to it.

A. Text Materials

1. Arc Welding in Design, Manufacture and Construction, 1939, LEC, 1408 pp., 695 illus. $1.50

Published by the J. F. Lincoln Arc Welding Foundation. The 109 articles presented are arranged in 10 sections, consisting of outstanding studies in a $200,000 Award Program written by 126 leaders in all fields of industry. Topics cover arc-welding procedures and practice in such fields as automotive, aircraft, railroad, watercraft, structural, furniture and fixtures, commercial welding, automotive repairs, welderies, containers, machinery, jigs and fixtures. These papers contain designs and explanations for the efficient use of arc welding in manufacture.

2. Welded Steel Construction, Hale, R. S., 1938, PITPCo., 170 pp. (A&O-A), 59 illus. $3.00

The author says, "This is not a treatise on the welding art, or the science of construction. It is a simple, concise exposition for architects, engineers, fabricators, contractors, welders, estimators, students and others who have a general knowledge of plans and structural engineering or welding." It is primarily a manual on the design, detailing, fabrication and erection of welded steel buildings, bridges and other steel structures. Included are many working sketches, photographs and tables of data, codes for welding on steel structures and a rather complete bibliography.

3. Arc Welded Steel Frame Structures, Fish, G. D., 1933, McGH, 401 pp., 211 illus. $5.00

A text written for the practicing engineer, architect and contractor, presenting the essentials of technology, structural theory, design, economy, cost estimating, shop drawings, welded details, and supervision as applied to the arc welding of steel frame buildings and bridges. Although this book is now rather old as welding progress goes, it is of value to those experienced in arc welding and design.

4. Instruction Material in Welding Developed by Staff of Dunwoody Industrial Institute, Minneapolis, Minnesota, 1940, ATS (A&O-A) $3.00

This is the Dunwoody plan of training welding operators, including an explanation and illustration of the organization and layout of courses and instructional material along with a definite procedure in carrying out the training program. It contains a Job List and samples of Job Analysis Charts, Progress Charts, Job Assignment Cards, Job Sheets, Job Sheet Check, Job Report, and Job Routing, as well as brief and terse step-by-step explanations. Of value to all welding instructors who wish to improve their shop technique, organization and management. Material is mimeographed.

5. Modern Shipfitter's Handbook, 2nd Edition, Swanson, W. E., CMP, 1941, 320 pp. (A&O-A) $2.50

Written by a master shipfitter in practical language understandable by ship construction workers. Covers briefly every phase of welded ship construction from mold loft to launching. Clear descriptions and over 200 working drawings explain blueprint reading; mold loft and structural shop work; anglesmithing; assembly of sections; erection on the ways; welding (15 pages); riveting, and launching. Contains a 28-page glossary of ship construction terms and a complete index. Valuable to shipyard welding operators who wish to become more familiar with other phases of ship construction.

6. Audel's Shipfitter's Handy Book, Newstead, R., 1940, TA&C, 252 pp. (A&O-A) $1.00

A manual on the entire shipfitting trade presented in simple form understandable by practical ship construction workers. Author has had 25 years' experience in shipfitting. Fifty pages devoted to theory and practice in arc welding and 24 to gas welding.

7. Welding Metallurgy, Vols. I and II, Henry, O. H., and Claussen, G. E., 1940, AWS, 359 pp., 140 illus., Vols. I and II under one cover (A&O-A) $1.50

A series of 18 lectures on the ABC of metallurgy and metallography dealing with the structure, properties and composition of welded materials, emphasizing the application of general metallurgical principles to the welding processes. Chapter titles include: heat and time in welding, the weld during cooling, brittleness and cracking, shrinkage, fluxes and slags, alloy steels, stainless steels, preheating and stress relief. Illustrated with numerous micrographs and diagrams. Questions follow each chapter. These lectures were sponsored by the New York Section of the American Welding Society. Not indexed.

8. Metallurgy and Wheels, Technical Data Department, 1938, GMC, 47 pp. **Free**

The story of men, metals and motors. A simple discussion of elementary metallurgy for the laymen, explaining the manufacture, alloying, heat treatment, properties and characteristics of iron and steel. Well illustrated with effective sketches. Should be read by all welding operators.

9. Metallurgy, Johnson, C. G., Dean, R. S., Gregg, J. L., 1938, ATS, 149 pp., 82 illus. **$1.50**

A practical and fundamental textbook for beginners that stresses the science of physical metallurgy rather than that of chemical metallurgy.

Contents: properties of metals and their uses, testing, chemical metallurgy, manufacture of iron and steel, physical metallurgy, iron-carbon diagram, shaping and forming metals, SAE steel specifications, carbon and alloy steels, powder metallurgy, etc. Covers the salient points but does not confuse the beginner by too much detail.

10. Working, Heat Treating and Welding of Steel, 2nd Edition, Campbell, H. L., 1940, JW&S, 230 pp., illus. **$2.25**

A concise and easy-to-read textbook describing steelmaking processes, composition and classifications of steel, mechanical working and heat treatments, welding processes, rust proofing. For the student and instructor interested in an elementary treatise on simple metallurgy. A series of laboratory assignments is appended to serve as a guide to the laboratory instruction usually given as a part of this course of study.

11. Production, Heat Treatment, and Properties of Iron Alloys, C-409, National Bureau of Standards, 1936, USS of D., 40 pp., 19 illus. **$ .15**

This circular was prepared by Louis Jordan of the Bureau of Standards' staff in response to many requests for a reasonably brief and simplified statement of the principles of the heat treatment of iron and steel, the production and properties of iron alloys in general, the meaning of common terms used in metallurgy and for simple directions for and explanations of such processes. It also describes very briefly the reduction of iron ore, the production and properties of cast irons, the production, structure, fabrication and uses of plain carbon and alloy steels, a description of the SAE steel numbering systems and tables showing the chemical composition of these classifications, the heat treatment of steel and heat-treating equipment. This not-too-technical and not-too-detailed publication should be very helpful to the serious-minded welding operator in gaining an understanding of the metals he commonly welds. A selected list of sources of reference material for further study of this subject is given. Diagrammatic sections of furnaces, equilibrium and quenching diagrams and micrographs of the structures of steels aid in better understanding the descriptive material.

12. Metallurgy and Metallography, HFTS, Revised 1940, 152 pp., illus. **$ .50**

This textbook is one of a series of lessons prepared by instructors in the Henry Ford Trade and Apprentice Schools for use in their classes. It is made up of four sections as follows: I—Elementary Chemistry, II—Physics, IV—Non-Ferrous Metallurgy, V—Metallurgy and Metallography of Iron and Steel.

Section I describes briefly chemical and physical changes, compounds, solutions, mixtures, formulas, and chemical reactions, and their relation to the metallurgy and metallography of metals. Section II treats of units of measurement, physical properties and characteristics of metals, and methods of testing. Friction, gas laws, heat, contraction and expansion of metals are briefly discussed. Section IV treats of the metallurgy and metallography of copper, zinc, aluminum, antimony, nickel and tin and their common alloys. Section V briefly discusses the metallurgy and the mechanical working and heat treatment of iron and steel to enable the student to better understand the different conditions existing in the metal due to these treatments, as seen under the microscope. Metallography is treated sufficiently to enable the instructor, inspector and advanced student in welding who has access to proper laboratory equipment to profit by this instruction.

Although this material is well illustrated and written in the simple and practical style of other lesson sheets prepared by these instructors, a fair understanding of elementary chemistry of the high-school level would almost be necessary to get the most from this course. A previous course in elementary physical science or physics would also be helpful but not so necessary.

This textbook would be particularly helpful in upgrading welding operators, welding inspectors and foremen, when used by an instructor who has had sufficient understanding in science applied to metallurgy and in the industrial practices in the metal working field. Some laboratory work and instructor-demonstrations are essential in connection with the text. Many illustrations are effectively used.

13. Airplane Welding and Materials, Second Edition, Johnson, J. B., 1941 G-W Co., 420 pp. 193 illus. (A&O-A) **$3.50**

Because of the possibility of greater application of arc welding in aircraft construction, this book is included. The technical material is well written, effectively illustrated, easy to understand and much of it is applicable to arc-welding practice. The author is Chief of the Materials Laboratory of the U. S. Army Air Corps at Wright Field and an authority on airplane welding and materials. The chapters of particular interest to arc welding operators are: III—Arc Welding, IV—Electric Resistance Welding, V—Physical Testing of Metals, VI—Aircraft Steels, VII—Properties of Oxy-acetylene and Arc Welds in Steel, XI—Manufacture of Weld Structures, XII—Welding Special Metals, XIII—Inspection of Welds. While this last chapter is written primarily for the inspector or mechanic who is responsible for the final acceptance of raw materials or the fabricated parts, the ample treatment of the magnaflux process is of interest to all serious welding operators. The appendices contain procedures for etching welded metals. Well indexed.

B. Periodicals

NOTE: Every welding school should subscribe to one or more magazines devoted wholly or in part to welding. Current periodicals usually contain news and articles on the most recent developments in the trade. *The Welding Journal* is distributed free to all members of the AWS as part of the services of the Society.

1. Welding Journal (Monthly), AWS, per Year (A&O-A) **$5.00**

The official publication of the American Welding Society and the Weld-

is made up of four sections as follows: I—Elementary Chemistry, II—

Welding Journal is distributed free to all members of the AWS as part of the services of the Society.

1. Welding Journal (Monthly), AWS, per Year (A&O-A) $5.00

The official publication of the American Welding Society and the Welding Research Committee of the Engineering Foundation. It contains: (1) articles describing the latest developments and applications of all welding processes, gas cutting and hard surfacing, (2) the latest codes, standards and specifications adopted by the Society, (3) articles and reports dealing with welding research, and (4) news items and articles on American Welding Society activities. Well illustrated.

2. The Welding Engineer (Monthly), WEP, per Year (A&O-A) $3.00

A technical magazine on the practical applications of welding, for supervisors, foremen and welding operators. All processes—electric arc, oxyacetylene, resistance, and thermit—on all metals are treated by leading authorities on welding. This magazine is easy to read and provides much practical and technical information along with interesting welding news. New product developments, current publication reviews, engineering data sheets, recent patents are among topics covered. Well illustrated.

3. The Welder's Stabilizer (Bi-monthly), LEC Free

This is a bi-monthly magazine on all phases of arc welding and is largely of direct interest to the welding operator. It is made up principally from articles and ideas submitted by welding operators and others interested in the practical side of welding. Well illustrated with photographs and sketches. Free to those concerned with welding.

4. Welding and Industry, IPC (Monthly) (A&O-A), per Year $1.00

This small monthly magazine devoted to industrial welding contains a wealth of practical trade information and interesting trade news and advertisements. The contents of a recent issue was as follows: free literature, welding machines speed housing program, removing rivets with the torch, qualifying welding operators in new programs, alloy section, oxyacetylene repair of locomotive frames, cost of welding, new ideas, new products, hints and facts, and solutions of interest to the trade. As in any other trade and technical magazines, leaders in the field of welding contribute up-to-date articles on progress in this field. Every phase of welding is included. Written in simple trade language, it is easily understandable by practical welding operators. Effective illustrations and drawings are extensively used.

5. The Iron Age (Weekly), CCo (A&O-A), per Year $6.00

A reference magazine published weekly for the iron and steel industry. Discusses principally applications of welding, cutting, machining, heat treating and iron and steel making practices. Carries news and advertisements of the industry. Considerable space is devoted to welding. The revised "41 Lessons in Arc Welding" prepared by the welding engineers of WE&M Co. was published weekly beginning with the February 20, 1941, issue. Well illustrated.

KEY TO ABBREVIATIONS USED IN APPENDIX D

(AIRCo)	Air Reduction Sales Co., Applied Eng. Dept., 60 East 42nd St., New York City, or nearest sales agency.
(ATS)	American Tech. Society, Drexel Ave. at 58th St., Chicago, Ill.
(AWS)	American Welding Society, 33 West 39th St., New York City.
(A&O-A)	Publication treats both arc and oxygen-acetylene welding processes.
(BBS)	Blue Book Series of I. C. S. Courses (See ITBC).
(ByersCo)	A. M. Byers Co., Clark Bldg., Pittsburgh, Pa.
(CCo)	Chilton Company, Publication Office, Chestnut and 56th Sts., Philadelphia, Pa. or The Iron Age Pub. Co., New York City.
(CMP)	Cornell Maritime Press, 350 West 23rd St., New York City.
(CRCo)	Champion Rivet Company, Cleveland, Ohio.
(GE)	General Electric Co., Schenectady, N. Y., or nearest sales agency.
(GMC)	General Motors Corp., Public Relations Dept., Detroit, Mich.
(G-WCo)	The Goodheart-Willcox Co., 2009 Michigan Ave., Chicago, Ill.
(HBCo)	The Hobart Bros. Co., Box EW-46, Troy, Ohio.
(HC)	Harnischfeger Corporation, 4510 W. National Ave., Milwaukee, Wisc.
(HFTS)	Henry Ford Trade School, Dearborn, Mich.
(ICS)	International Correspondence School, Scranton, Pa. (See ITBC.)
(IPC)	Industrial Publishing Company, 812 Huron Road, Cleveland, Ohio.
(ITBC)	International Textbook Co., Scranton, Pa.
(JW&S)	John Wiley & Sons, 440 Fourth Ave., New York City.
(LEC)	The Lincoln Electric Co., 12818 Coit Rd., Cleveland, Ohio.
(McGH)	McGraw-Hill Book Co., 330 West 42nd St., New York City.
(MLICo)	Metropolitan Life Insurance Co., 1 Madison Ave., New York City.
(NSC)	National Safety Council, Inc., 20 N. Wacker Drive, Chicago, Ill.
(NYC)	New York City.
(PITPC)	Pitman Publishing Corp., 2–6 West 45th St., New York City.
(TA&C)	Theo. Audel & Co., 49 West 23rd St., New York City.
(USSofD)	Superintendent of Documents, Washington, D. C.
(WE&MCo)	Printing Department Order Service, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa. or nearest Westinghouse Office.
(WEP)	Welding Engineer Publishing Co., 506 S. Wabash Ave., Chicago, Ill.
(WPFP)	Write publisher or manufacturer for price. Often considerable discount is given for quantity orders and to schools. Free copies are often supplied to purchasers of manufacturer's equipment. Cash with order is sometimes required.

(*Continued from page 612*)

Tanks. Welded Fabrication of Copper Tank. Oxy-Acetylene Tips, vol. 20, no. 7 (July 1941), pp. 162–163.

Tubes, Welded Steel. Study of Welded Pipe Truss Construction, F. A. Weitzel. Welding Engr., vol. 26, no. 5 (May 1941), pp. 33–38.

Tugboats, Diesel, Welded Steel. Upside Down Diesel Tugs. Diesel Progress, vol. 7, no. 5 (May 1941), pp. 34–35.

Welded Steel Structures. Design of Continuous Beams and Frameworks with Rigid Connections in Welded Construction, with Special Reference to Professor Hardy Cross's Method of Analysis—I, H. V. Hill. Welder, vol. 12, no. 77 (Nov.-Dec. 1940), pp. 161–167.

Welders, Training. How to Get Welding Operators, H. Lawrence. Steel, vol. 109, nos. 1 and 2 (July 7, 1941), pp. 60, 62, 102 and 104 and (July 14) p. 82, 84 and 86.

Welding. Fabricating Low-Cost Industrial Equipment. Oxy-Acetylene Tips, vol. 20, no. 6 (June 1941), pp. 125–129.

Welding. Facts and Figures—Statistical Review of Welding Industry. Welding Engr., vol. 26, no. 5 (May 1941), pp. 39–50.

Welding. Quarter Century of Welding, T. B. Jefferson. Welding Engr., vol. 26, no. 5 (May 1941), pp. 21–24 and 38.

Welding Shops. Layout of Modern Resistance Welding Shop, E. S. Waddington. Sheet Metal Industries, vol. 15, no. 170 (June 1941), pp. 797–798 and 800.

Welds, Stress Relief. Portable Stress-Reliever Controlled Automatically. Steel, vol. 108, no. 26 (June 30, 1941), pp. 72 and 74.

Welds. Testing. Weld Quality Checked Visually, A. Madson. Iron Age, vol. 147, no. 26 (June 25, 1941), pp. 50–51.

Arc-Welded Wind Tunnel at Langley Field

By A. F. Davis*

SHOWN in the accompanying illustrations are views of the completed wind tunnel at Langley Field, Virginia, and some of the large welded parts. Fabrication of this structure was by Pittsburgh Des Moines Steel Company, Neville Island, Pittsburgh, Pennsylvania.

Illustrations show: Fig. 1, the complete structure; Fig. 2, entrance door to test room; Fig. 3, high velocity intake section; Fig. 4, a corner section of the girder and vanes; Fig. 5, the arc welded de-compression chamber through which workers pass entering and leaving the tunnel while it is in operation.

* Vice-President, The Lincoln Electric Company, Cleveland, Ohio.

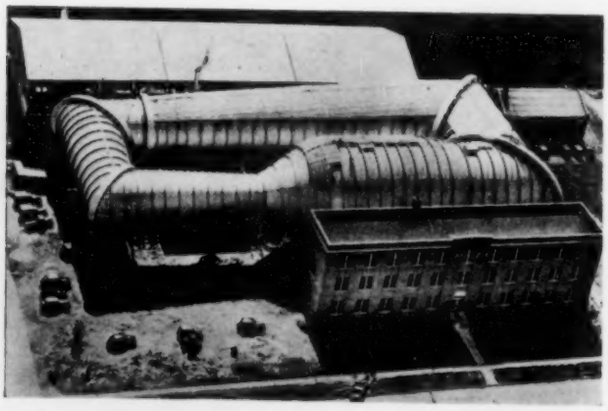


Fig. 1—New Wind Tunnel Recently Completed at Langley Field, Virginia

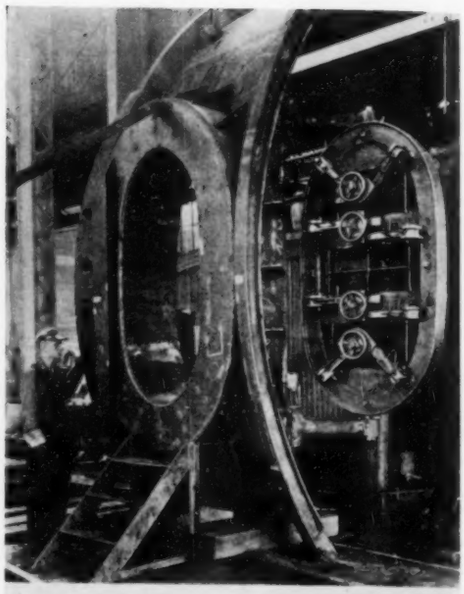


Fig. 2

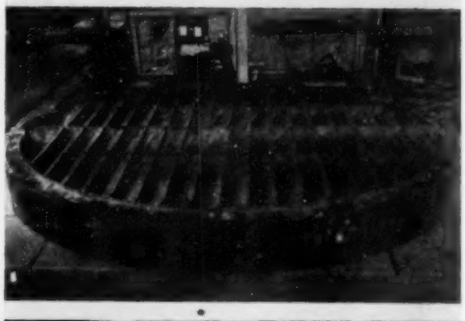


Fig. 3

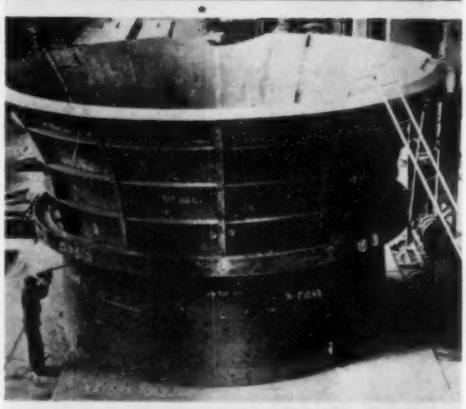


Fig. 4

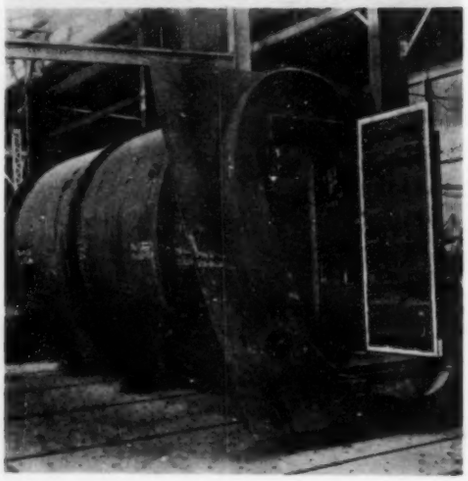


Fig. 5

Never too busy to be Good Neighbors

THERE are a lot of workers in the Bell System — about 350,000 of them. That's a big family and it likes to be a friendly kind of family.

Whether it be the installer in the house, the people in our offices, the operators or the lineman on the roadside helping to rescue a stray kitten for a worried youngster, telephone workers are close to the public and the tradition of the job is helpfulness.

Even in these days when the needs of defense place sudden and increasing demands on telephone workers, they are never too busy to be good neighbors.

Bell Telephone System

"The Telephone Hour" is broadcast every Monday. (N. B. C. Red Network, 8 P. M., Eastern Daylight Saving Time.)

Welding Society

ACTIVITIES — Related Events

THE PRESIDENT'S MESSAGE

What constitutes a proper training for engineering students is a question that never fails to bring out differences of view-points. Shall training be limited to fundamentals or must it be confined to applied subjects? Must the student be trained so that he immediately fits into some niche in industry or should industry expect to give some practical training before the young engineer is capable of productive work? Should students specialize on the type of functional work they wish to enter or should the young engineer seek the type of engineering work only after he has served an internship in industry? Other questions might be raised only to disclose no unanimity of thought.

The only result of this fluidity of thought can be uncertainty in our educational institutions as to how engineers should be trained. Some of our institutions may have fixed opinions and policies but they are not standardized. In this freedom of thought and individual development there is an opportunity for the student in a dynamic industrial society, but a serious handicap in a standardized mature society. Unless we have the courage to foresee an ever-changing world of new frontiers and new horizons, we should not teach our students to think; we need train them only to operate what has already been developed.

In a branch of engineering as infant as welding these and many other questions may be raised as to the training of the future welding engineer. There is the right to use the term welding engineer because we have specialists in this field. We have engineers whose professional life is being devoted to that one branch of industry. These specialists were not trained in welding for it is only recently that some engineering schools have offered courses in welding. But with a background of training in various fields of engineering they have become experts and are carrying on the development of welding at a rapid pace. The technical literature of the past decade indicates the rate of progress. The list of research problems still untouched is proof that the welding engineer has the imagination to visualize what scientific facts and relationships are essential to rationalize the art of welding and its applications.

Possibly we are approaching the development of engineering from the wrong direction. Our progress in the arts and sciences and their applications in industry would be far more rapid and the economy of industry would be far greater if the industrial executive could be given an adequate course of training through which he has a better appreciation of the value and application of engineering in its various phases.

Our engineering schools are devising various methods to keep abreast of the developments of science and engineering. Of course it cannot be expected that our training courses will be on the level of scientific and engineering practice in industry. Numerous conferences have been organized by our schools with the objective of bringing instruction close to the level of industrial application.

In all industry the most important tool is the human brain. We have the record of accumulated knowledge but it is our fate that we must progress. We can well afford to devote some of our thinking on this question of training. It is insufficient for the educator alone to consider this problem. He has imperfect opportunity to observe the effects of the theory and practice of his training courses. The solution of these questions requires also the thinking and expression of the industrialist and his specialized engineering staff.

It is the privilege and the duty of the AMERICAN WELDING SOCIETY to organize and foster conferences on such questions. Our Educational Committee will provide the forum for the expression of your views.

1941–1942 OFFICERS AMERICAN WELDING SOCIETY

Since no nominations other than proposed by the Nominating Committee have been made by 25 qualified members, as prescribed by the By-Laws, the nomination ballots are treated as election ballots. Accordingly, the following have been elected to office for the year to begin on the adjournment of the 1941 Annual Meeting. These officers will be declared elected at the Business Session of the Annual Meeting.

President, G. F. Jenks, Colonel, Ordnance Dept., U. S. Army, Washington, D. C.

First Vice-President, K. L. Hansen, Consulting Electrical Engineer, Milwaukee, Wis.

Second Vice-President, David Arnott, Vice-President, American Bureau of Shipping, New York, N. Y.

Treasurer, O. B. J. Fraser, Director of Technical Service, International Nickel Co., New York, N. Y.

Directors at Large: Frank B. Bolte, Process Engineer, Boeing Aircraft Co., Seattle, Wash.; R. W. Clark, Welding Engineer, General Electric Co., Schenectady, N. Y.; F. L. Plummer, Research Engineer, Hammond Iron Works, Warren, Pa.; R. G. LeTourneau, President, R. G. LeTourneau, Inc., Peoria, Ill.

District Vice-Presidents: New York and New England—E. R. Fish, Chief Eng., Boiler Div., Hartford Steam Boiler Insp. & Ins. Co., Hartford, Conn. Middle Eastern—A. G. Bissell, Senior Welding Engineer, Bureau of Ships, Navy Dept., Washington, D. C. Middle Western—L. S. McPhee, Welding Supt., Whiting Corp., Harvey, Ill. Southern—J. A. Hall, Engineer of Plate Construction, Kansas City Structural Steel Co., Kansas City, Kans. Pacific Coast—N. F. Ward, Associate Prof. M.E., University of Calif., Berkeley, Calif.

WELDING FELLOWSHIPS

Two graduate fellowships in the field of structural steel welding research are available at two leading universities in the East. Applicants should hold the B.S. degree in Civil Engineering. The recipients of these fellowships receive an annual stipend of $600 to $750 together with opportunity of working for the M.S. degree with freedom from tuition fees. The holders are expected to devote one-half time to research programs approved by the Structural Steel Welding Committee of the A. W. S. The research opportunities and graduate study afford an excellent basis of training for later positions in the welding industry. Applicants should forward complete qualifications immediately to Professor Bruce Johnston, Lehigh University, Bethlehem, Pa., and Professor F. M. McCullough, Carnegie Institute of Technology, Pittsburgh, Pa.

MEETING EXECUTIVE COMMITTEE, AMERICAN WELDING SOCIETY JULY 23, 1941

Present: President Jenks, C. A. Adams, David Arnott, A. G. Bissell, H. C. Boardman, R. W. Clark, E. V. David, O. B. J. Fraser, George Mikhalapov (representing J. D. Gordon), H. O. Hill, D. S. Jacobus, L. S. Moisseiff, W. Spraragen, Technical Secretary, and M. M. Kelly, Secretary.

Finances

In reviewing statements of assets and liabilities for the 9 months' period ending June 30, 1941, the Treasurer called special attention to the betterment of actual operations over budget by approximately $4000 net.

75,000,000 POUNDS OF THEM!

275,000,000 pounds is a lot of anything—especially welding electrodes.

But it's not enough to serve the needs of the arc welding industry in 1941—even though this figure is approximately twice that of 1940!

Through enlarged plant capacities (our own new plant, at East Chicago, Indiana, for instance, has doubled our production rate), new machines and additional shifts, electrode manufacturers are doing their best to meet the fast growing demands.

In the meantime, electrode buyers can minimize the chance of not having electrodes on hand when needed by ordering electrodes at the same time that they order the steel for each job.

It is vitally important today to get maximum speed in welding production. Our engineers, trained in working with manufacturers in many industries, will be glad to give you the benefit of their wide experience in welding.

METAL & THERMIT CORPORATION • 120 BROADWAY, NEW YORK

ALBANY • CHICAGO • PITTSBURGH • SO. SAN FRANCISCO • TORONTO

MUREX HEAVY COATED ELECTRODES

THERMIT WELDING — STANDARD FOR 40 YEARS FOR WELDING RAILS AND HEAVY EQUIPMENT

Promotional Membership Literature

A request of the Membership and Publicity Committees chairmen for an increased appropriation to get out an attractive new membership folder was approved.

A. W. S. Retirement System

The Finance Committee recommended (1) that a Pension Plan be devised, that would involve a total payment by the Society not to exceed $1000 annually at present, with an equal payment to be made by the employees of the Society, and (2) that a Pension Committee be appointed, consisting of 3 members, comprised of the Treasurer of the Society, a member of the Board of Directors and a representative of the Society employees, whose functions would be to consider and prepare a detail pension plan, administer its funds and make necessary investments; the proposed plan to make provision for years of past service, for suspension of payments by the Society in lean years, and for equitable adjustment when, as and if, Social Security Act requires diversion of financial support in such a manner as will not increase the cost to the employer.

Report of Special Committee to Study Technical Organization

In reviewing the Committee's recommendations, the Chairman stated that the principal change is the complete re-orientation of the Outline of Work Committee, now made up of 5 members of the Board of Directors, with the first or second vice-president of the Society as Chairman, and as proposed, to be made up of the chairmen of the various technical committees, with a chairman and vice-chairman elected by its own members, but not necessarily from its members—these officers to be members of the Society and ex-officio members of the Executive Committee.

At the present time the Executive Committee and Board of Directors have the final word on the technical contents of standards. It is now proposed to leave the judgment of technical contents of standards solely to the technical committee concerned, subject to the control of the Committee on Outline of Work. The purpose of the proposed change is to get useful results in the shortest possible time, to place responsibility for technical contents of standards in accordance with the practice of other standardization bodies, to simplify the standard work of the Society and to provide for a rational method by which the directorate may contact and direct the Society's standards work.

Consideration was next given to the following proposed modifications of By-Laws to put these principles into effect.

Article VIII—Section 1 (j)—"Committee on Outline of Work—Organization and Functions."

The article as approved reads—

"A Committee on Outline of Work which shall consist of the Chairmen of all the Technical Committees of the Society. It shall have a Chairman and a Vice-Chairman, who shall be members of the Society and shall be elected by the Committee's membership, but not necessarily from its own ranks. These officers shall serve for a period of two years, and shall be ex-officio members of the Executive Committee. The Committee shall have a Secretary, who shall be the Technical Secretary of the Society."

"The scope of this Committee shall be: to promote the standardization activities of the Society; to recommend policy, scope and organization of such activities, and methods and means of cooperating with other standardization bodies, including the nomination of official representatives of the Society on committees of other societies or standardization bodies; to pass upon recommended practices, standards and codes with respect to compliance with prescribed procedure and regulations; to decide questions of jurisdiction of Technical Committees; to review annually (at the Annual Meeting of the Society) the progress of the Society's standardization work; and to act in an advisory capacity to the Board of Directors in respect to standardization program."

In respect to the new Outline of Work Committee organization, it is expected that the new Committee will draw up rules under which it will operate and endeavor to arrange the agenda of each meeting to include only subjects of interest to certain groups, thus necessitating attendance of members only at certain meetings.

Article VIII—Section 1 (k)—"Technical Committees"

The paragraph as reworded reads:

"(k) Technical Committees, not limited in number, the scope of each of which shall be: to establish an organization; to recommend the scope of its work and its committee membership; to prepare and recommend the acceptance or withdrawal of standards and revisions thereof within its jurisdiction; to report conflicts of jurisdiction to the Committee on Outline of Work; to report on the progress of its work; and to carry out such other activities as may be approved by the Outline of Work. Technical Committees shall operate according to the latest revision of Rules to Govern Organization, Functions and Operations of Technical Committees of the AMERICAN WELDING SOCIETY."

Further it was

Voted: That the Rules of Procedure proposed by the Special Committee be approved in principle subject to editorial and other modifications required by the actions taken at this meeting on the Report of the Special Committee on Technical Organization and resubmitted to the Executive Committee and Board of Directors.

Certification of Welders

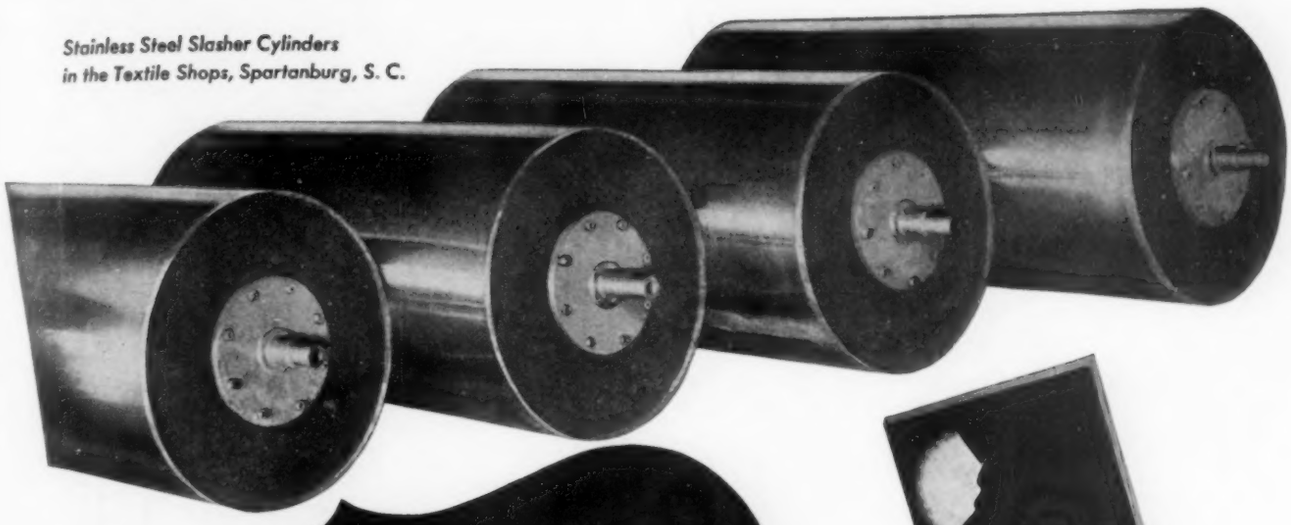
For the guidance of the Public Relations Committee, it was,

Voted: That under no condition shall the AMERICAN WELDING SOCIETY issue a Certificate to a welding operator, nor

INDEX TO ADVERTISERS

Air Reduction Sales Co. ..... Outside back cover
American Brass Company 651
American Society for Metals 661
American Telephone & Telegraph Co. 645
A. W. S. Annual Meeting 665
Anti-Borax Compound Company 658
Bastian-Blessing Co. 656
General Electric Co. 652, 653
Hobart Brothers Co. 573
Jewel Manufacturing Company 660
Kelley-Koett Mfg. Co. 659
Lenape Hydraulic Pressing & Forging Co. 575
Lincoln Electric Co. ..... Inside back cover
The Linde Air Products Co. 576
P. R. Mallory & Co., Inc. 658
Metal & Thermit Corporation 647
National Carbide Corporation 654
Oakite Products, Inc. 656
Page Steel & Wire Division 649
Progressive Welder Co. 663
Resistance Welder Mfrs. Association 655
Shawinigan Products Corp. 658
Stulz-Sickels Company 660
Union Carbide & Carbon Co. 576
U. S. Steel Corp. Subsidiaries 657
Victor Equipment Co. ..... Inside front cover

Stainless Steel Slasher Cylinders in the Textile Shops, Spartanburg, S. C.



Page-Allegheny

STAINLESS STEEL ELECTRODES for your stainless welding

To make certain, when you weld Stainless, that the metal in the weld equals the metal you are welding, the first step is to tell your local PAGE Distributor the Stainless Analysis. He will provide the correct electrode—made by PAGE in operation with the world's largest producer of Stainless Steel.

These PAGE-Allegheny Stainless Steel Electrodes are for shield-arc welding and provide the high speed, low spatter and slag loss and smooth beads you want in all top quality welding. They are suitable for use on horizontal, vertical or overhead jobs.

Ask your local PAGE Distributor for the 12 page booklet on PAGE-Allegheny Electrodes. It contains valuable information to everyone welding Stainless Steel.

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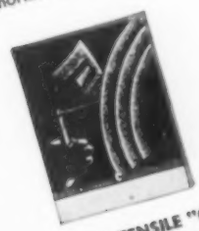
Ask your local PAGE Distributor for a copy of this booklet.

PAGE HI-TENSILE "F." A shield-arc type electrode for vertical, horizontal or overhead welding.



PAGE HI-TENSILE "C" A shield-arc type electrode for maximum strength, penetration and uniformity—vertical, horizontal or overhead welding.

In Business for Your Safety

PAGE ELECTRODES

PAGE STEEL AND WIRE DIVISION
MONESSEN • PENNSYLVANIA

AMERICAN CHAIN & CABLE COMPANY, Inc.

support a plan for the certification of welding operators, that denies a fabricator the privilege of qualifying his own welding operators.

In regard to the qualification of welding operators for marine construction, Mr. Bissell reported that the Bureau of Ships, the Bureau of Marine Inspection and the American Bureau of Shipping are contemplating a reciprocal agreement whereby welding operators qualified for one Bureau would be qualified for the other. In order that the full advantage of such agreement may be realized during the present emergency, it is planned by the Bureau of Marine Inspection and Navigation, American Bureau of Shipping and the Navy Department to hold a round-table discussion to consider universal acceptance of such agreement. To such conference will be invited representatives from the Coast Guard, War Department, A. S. M. E. Boiler Code Committee, A. S. A. Pressure Piping Committee, A. P. I.-A. S. M. E. Unfired Pressure Vessel Code Committee, Hartford, Steam Boiler Inspection and Insurance Co., Fidelity and Casualty Company, Maryland Casualty Company, Lloyds Register of Shipping and the A. W. S. Committee on Standard Qualification Procedure.

Meetings and Papers Committee

The recommendation of the Meetings and Papers Committee for the dissolution of that Committee and for the creation of two separate committees, one on Meeting Programs, and the other on Publications was approved.

Recommendations of Outline of Work Committee

The recommendations of the Committee on Outline of Work for the following additions to the Resistance Welding Standards Committee were approved:

H. P. Heath, Western Electric Co., to replace F. E. Henderson of the same company; L. E. Earnest, Solar Aircraft Co., Lindbergh Field, San Diego, Calif.; W. J. Van den Akker, Ryan Aeronautieal Co., San Diego; H. L. Chiles, Lockheed Aircraft Corp., Burbank, Calif.; V. N. Krivobok, Lockheed Aircraft Corp., Burbank, Calif.; P. Altman, Vultee Aircraft, Detroit, Mich.

The publication of Report on Thermal Stresses and Shrinkage in Welded Ship Construction was authorized.

A. W. S.-A. W. W. A. Tentative Specification for Elevated Steel Water Tanks, Standpipes and Reservoirs

It was voted that the recommendation to advance from a Tentative Standard to a Standard, the A. W. S.-A. W. W. A. Specification for Elevated Steel Water Tanks, Stand pipes and Reservoirs, be approved.

Welded Bridge Specifications

It was reported that the revised Welded Bridge Specifications have been set up in type and it is the plan to submit them to the Outline of Work Committee and the Executive Committee for approval by letter ballot.

Code of Minimum Requirements for Instruction of Welding Operators

Because of the serious and immediate need for this code in connection with the National Defense Training Programs, it was recommended in this instance to follow the new Rules of Procedure governing Technical Committees, namely, when the rules are turned over by the Committee on Minimum Requirements, and have been approved by the Outline of Work Committee, to publish them in the Society JOURNAL for the purpose of securing comments.

Yearbook Publication

The Publications Committee offered the following recommendations:

That the Yearbook be published as Section 2 of the December WELDING JOURNAL and of the same page size as the JOURNAL in order to take advantage of the low mailing cost (second class mailing rates), and the reduced printing cost resulting from having the book printed of the same page size as the JOURNAL; that the Yearbook be furnished to all members of the Society. Upon motion duly seconded, these were approved.

By-Law Amendments

Inasmuch as proposed By-Law changes are submitted to the membership of the Society for vote by letter ballot they are not reproduced here.

Section Advisory Committee

Voted: To approve the following addition to Article VIII, Section 1 (*o*), "A Section Advisory Committee to act in an advisory capacity to the Board of Directors in all matters pertaining to the activities of the Sections of the Society, and to be responsible for planning and conducting Section Officers Conferences. The Committee to consist of six members who are not directors of the Society; two members to be appointed for a term of one year; two members for a term of two years; and two members for a term of three years; two new members to be appointed each year thereafter for a term of three years. No member is to be reappointed until at least one year has elapsed since the completion of his last term."

Resistance Welding Advisory Committee

For the time being it was felt that the Committee should be included in the Yearbook under the caption "Advisory Committees" and that the organization and scope should be as follows:

"A resistance Welding Advisory Committee to make to the Executive Committee such recommendations as may insure the most efficient utilization of the A. W. S. for the advancement of the art and science of resistance welding, the Committee to consist of six members; two members to be appointed for a term of one year; two members for a term of two years; and two members for a term of three years. No member is to be reappointed until at least one year has elapsed since the completion of his last year."

INDUSTRIAL SPECIALISTS MAY STILL APPLY FOR GOVERNMENT JOBS

The Government continues its search for specialists in all branches of industry and business. The Federal Civil Service examination for Industrial Specialist, announced on July 7th, has been amended to remain open for receipt of applications until further notice.

The National Defense Program needs men with experience in one or more of the following fields:

Iron and steel
Non-ferrous metals
Machine tools
Ordnance
Aircraft, marine and automotive equipment
Railroad repair shops
Radio and other electrical equipment, supplies and apparatus
Textiles
Forest products
Paper
Printing and publishing
Chemicals and allied products
Plastics
Petroleum and coal products
Rubber products
Stone, clay and glass products
Leather and its manufactures
Food and kindred products

Salaries range from $2600 to $5600 in the various grades. No written examination is given. Application forms may be obtained from Civil Service Representatives at any first- or second-class post office or at a Civil Service District Office.

AMENDMENTS OF BY-LAWS

The recent proposed ammendments to the By-Laws submitted to the membership for letter ballot vote have been approved. These cover changes in Article III, Section 3, Organization; Article V, Section 5, District Meetings; additional sections governing Conventions, Manufacturers, Publicity and Public Relations Committees, and Article IX, Exhibitions. These changes will be incorporated in the By-Laws to be published in the Year Book of the Society in December.

SEAM WELDERS

A very attractive bulletin on "Seam Welders" has just been issued by the Taylor-Winfield Company. This pamphlet describes the general specifications, types and equipment available, and also gives some important engineering seam-welding data. Copies are available on request.

A YEAR'S DELAY SAVED BY BRONZE WELDING!

Fractured spokes of 24 ft. flywheel repair-welded with Anaconda 997 Low-Fuming Bronze Rod in 56 man hours

When two spokes of this giant flywheel were broken, it appeared as though a blast furnace with scheduled defense production would be out of operation for a long time.

The Hebeler Welding Company, Buffalo, was called in as soon as it was learned that a new wheel probably could not be delivered for a full year.

In just 56 man hours, the Hebeler men completed the job with about 300 pounds of Anaconda 997 Low-Fuming Welding Rod. An insurance company then insured the repaired wheel, which once again proves the statement that good workmanship plus a good material equals dollars—and time—saved!

41187-A

ANACONDA from mine to consumer

Anaconda Welding Rods

THE AMERICAN BRASS COMPANY, General Offices: Waterbury, Connecticut

In Canada: Anaconda American Brass Ltd., New Toronto, Ont. • Subsidiary of Anaconda Copper Mining Company

New WELDERULE *gives*

★ **Order Yours Today**

★ **Handy Vest-pocket Size**

★ **Another G-E Welding Service That Saves You Time, Money, and Material**

The WELDERULE Tells at a Glance:

(1) Weld footage obtainable from popular types and sizes of G-E arc-welding electrodes when applied to commonly used types and sizes of joints.

(2) Weight of deposited weld metal obtainable per 100 lb of electrodes so that weld footage can easily be calculated for unlisted and unusual types of joints.

(3) Types of electrodes which meet the various classes of filler metal as specified by A.W.S.

Here's How It Works—

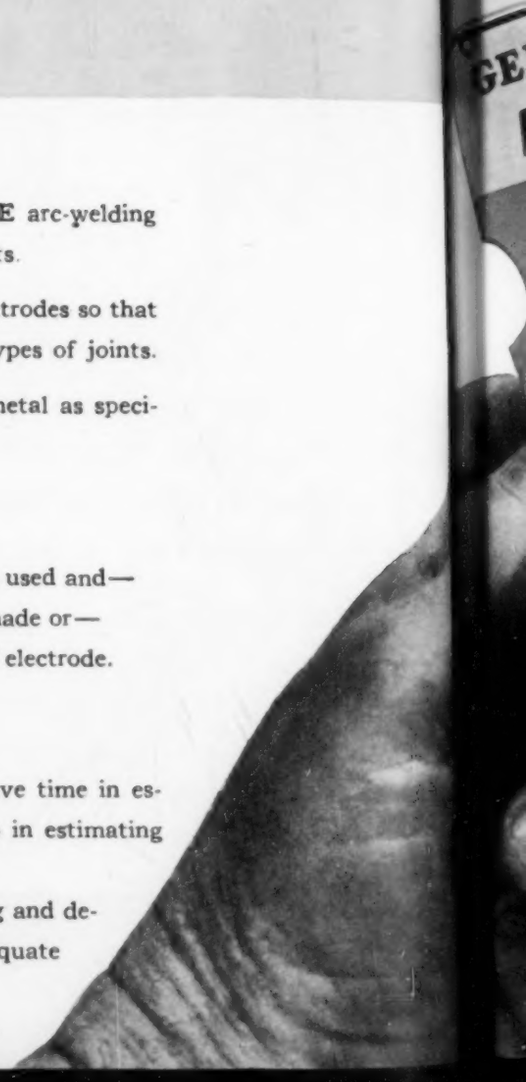
Merely pull the slide to show the type and size of electrode being used and—
Read the weld footage opposite the type and size of joint to be made or—
Read the weight of deposited weld metal obtainable per 100 lb of electrode.

Who Needs the WELDERULE—

Designers, architects, supervisors, operators, and foremen—to save time in estimating quantities of electrodes required for different jobs, also in estimating welding costs.

Purchasing agents and production men—to help correlate buying and delivery schedules with production requirements, thus assuring adequate supplies without excesses.

Mail the coupon or call or write your local G-E arc welding distributor today.



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you the answers

ON ELECTRODE SELECTION AND COSTS

in a flash!

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ARC WELDERULE
14" LENGTH
Read feet of weld per 100 lbs. of electrode.
LBS. DEPOSITED PER 100 LB. ELECTRODES
HORIZONTAL FILLET WELD
FLAT FILLET WELD
U JOINT WELD
SET TYPE AND SIZE OF ELECTRODE HERE
18" LENGTH
Read feet of weld per 100 lbs. of electrode.
SELECTOR CHART
AWS Class
Welding Position
Welding Current
Type Electrode
All data based on 2 in. stub ends and on joints having good fit-up
GENERAL ELECTRIC COMPANY
SCHENECTADY, N. Y.
GENERAL ELECTRIC
W-24
5/16" x 14"
SCHENECTADY, N. Y.
PRODUCTION DATA
This 50 lb. box of electrodes will produce 30.2 lb. of filler metal in joint, based on 2" stub ends.
Welding production is estimated as follows:
MADE IN U.S.A.

A LIMITED SUPPLY

PRICE 25¢ EACH

To facilitate your on-the-job and stock-room estimates, production data is available on the cartons of G.E.'s heavily coated, mild-steel electrodes, "all-position" types W-20, -22, -25, -30 (⅛- to ¼-in. diam) and "flat-position" types W-23 and W-24 (¼-in. to ⅜-in. diam). Data on other sizes on request.

MAIL COUPON TODAY

General Electric Company,
Electric Welding Section
Schenectady, New York

Here is my.....cents. Please send.....of the New WELDERULES to:

Name.....

Company.....

Address.....

City.....*State*.....

673-21-8748

FOUND—A NUMBER OF KEYS

On July 22nd there was found on Michigan Ave., Chicago, a number of keys on a chain. Since this chain also carried a souvenir medal from the 1939 Golf Tournament of the Chicago A. W. S., the owner may obtain these keys by calling at *The Welding Engineer*, 506 South Wabash Ave., Chicago, Ill.

FISHER JOINS PROGRESSIVE WELDER CO.

Edwin Fisher, associated for the past thirteen years with the Cadillac Motor Car Company, and for the past four years Manager of Cadillac Jefferson Ave. Branch in the Detroit Area, has resigned from G. M. to join Progressive Welder Company in an executive sales capacity.

In his new connection, Mr. Fisher will assist in the development of sales of Progressive Welder's resistance welding equipment in the middle Western area.

HANDY & HARMAN SALES MANAGERS

Recent changes in the Handy & Harman organization have brought J. W. Colgan, formerly manager of Handy & Harman of Canada Ltd., Toronto, back to New York in the capacity of sales manager of the parent company. Jack, as so many know him, is not a stranger to the trade in this country, having seen 17 years of service in the New York sales department before going to Toronto five years ago. He is taking charge of all company sales work connected with the silversmith and jewelry industries, as well as the growing industrial work in which the company is now engaged.

ROBERT M. MAINS JOINS LEHIGH LAB.

Mr. Robert M. Mains, formerly instructor at the Missouri School of Mines, has been appointed Engineer of Tests at the Fritz Engineering Laboratory of Lehigh University. He will take up his duties on September 1st and succeeds Mr. Howard J. Godfrey, who has returned to John A. Roebling Sons Company in their research and development department. Dr. Bruce Johnston, previously Assistant Director of the Fritz Laboratory, has been named Associate Director and Associate Professor of Civil Engineering.

G. E. ADDS WELDING SPECIALIST IN NEW YORK DISTRICT

E. J. Lassen has been appointed manager of General Electric welding sales for the New York District, according to an announcement by G. H. Reid, manager of the G-E New York District Industrial Department. He will work with E. Vom Steeg, Jr., G-E welding specialist, and with the Welding Engineering Sales Corporation, G-E distributor, in serving northern New Jersey, New York State and Connecticut.

Mr. Lassen became affiliated with General Electric in 1934 as a "testman," after being graduated from North Carolina State University with a Bachelor of Science degree in Mechanical Engineering. After completing test, he was transferred to the job of handling G-E advertising and sales promotion on welding, later being transferred to the company's New York Office, where he was closely associated with the sales promotion activities of General Electric's agents and arc-welding distributors in that territory. Previous to his new appointment, Mr. Lassen was engaged in welding application engineering work at Schenectady.

RESISTANCE WELDING DATA BOOK

The second edition of the *Resistance Welding Data Book*, devoted to the theory and practice of resistance welding, and generally adopted by the welding industry as a textbook on the subject, has just been issued by P. R. Mallory & Co., Inc., Indianapolis, Indiana.

There are four sections in the new edition: (1) Fundamentals of Resistance Welding; (2) Materials to Be Welded; (3) Alloys for Resistance Welding Applications; (4) Miscellaneous Tables.

Much new material has been added to bring the book up to date. Of particular value to welding engineers, production executives and machine operators, the Data Book is available at no cost when requested on a company letterhead.

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Carbide

DEPENDABLE

EFFICIENT

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FOR WELDING and CUTTING

Use National Carbide in the Red Drum

Lincoln Building — NATIONAL CARBIDE CORPORATION — New York, N. Y.

IF YOU CAN DO THIS WITH YOUR PRODUCT....

Keep these simple illustrations of Spot, Seam and Flash Welding in mind.

They show what Resistance Welding can do . . . why it can give you more and better production at lower cost . . . why more and more manufacturers are turning to Resistance Welding to help solve metal joining or assembly problems.

Modern Resistance Welders are precision mass production machines capable of turning out accurate, uniform work at high speed and low cost. They seldom require highly skilled operators of the type so hard to find today. They are available in an almost unlimited range of types and sizes to suit practically any product, material or production requirement.

An experienced welding engineer, representing one of the member companies listed here, can tell you quickly just what Resistance Welding will do for you. Why not call him in today?

RESISTANCE WELDER MANUFACTURER'S ASSOCIATION

505 Arch Street **Philadelphia, Pa.**

RESISTANCE WELDER MANUFACTURERS ASSOCIATION · RWMA

MEMBER COMPANIES

Welding Machines Mfg. Company, Detroit, Mich.
Acme Electric Welder Company, Los Angeles, Calif.
American Electric Fusion Corporation, Chicago, Ill.
Eisler Engineering Company, Newark, N. J.
Expert Welding Machine Company, Detroit, Mich.
Federal Machine and Welder Company, Warren, Ohio
Multi-Hydromatic Welding and Manufacturing Co., Detroit, Mich.
National Electric Welding Machines Co., Bay City, Mich.
Progressive Welder Company, Detroit, Mich.
Swift Electric Welder Company, Detroit, Mich.
Taylor-Hall Welding Corporation, Worcester, Mass.
Taylor-Winfield Corporation, Warren, Ohio
Thomson-Gibb Electric Welding Co., Lynn, Mass.

ASSOCIATE MEMBER COMPANIES

P. R. Mallory and Co., Indianapolis, Ind.
S-M-S Corporation, Detroit, Mich.
Electroloy, Inc., New York, N. Y.
Welding Sales and Engineering Co., Detroit, Mich.

BATTELLE RESEARCH ENGINEER

C. B. Voldrich has been named a research engineer on the technical staff of Battelle Memorial Institute, Columbus, Ohio, where he will assist in the Institute's program of welding research.

Mr. Voldrich has had a wide experience as a welding engineer. Previous to joining the Battelle staff, he was associated

for four years with the Navy's Bureau of Ships. Earlier he was a research engineer with the A. O. Smith Corporation, Milwaukee, Wisconsin.

He is a graduate of Purdue University and the University of Wisconsin and is a member of The American Society for Metals, AMERICAN WELDING SOCIETY and an associate member of Sigma Xi, national honorary science society.

AEROSPHERE 1941

That aviation is rapidly becoming a major factor in our modern world will not be doubted by those who take the trouble to investigate the scope of its activities and the ramifications of its influence. *Aerosphere* is a serious and successful attempt to serve those who wish to obtain a broad perspective of the aviation industry.

Aerosphere 1941 embodies the whole world's aviation—civil and military.

Aerosphere 1941 is published for the dual purpose of being a useful daily working tool in all branches of the aviation industry, and completely informative to the alert lay reader who searches for basic knowledge of our newest transporation medium and industrial colossus. The current $6,000,000,000 backlog emphasizes and gives point to the purpose of, and need for, this second edition of *Aerosphere*.

Here are some who will particularly want *Aerosphere 1941:* Aviation Industry Executives, Engineers and Purchasing Departments; Transport Executives; Private Pilots; U. S. Army and Navy Officials; Foreign Air Attaches; Students in all branches of learning; Journalists; Mechanics; Advertising Agencies; Export Representatives; Airport Repair Shops; Publishers of all kinds of Books, Periodicals and Newspapers; College and Public Libraries; Financial houses; Motion Picture Directors and Producers . . . and many others! Every person who has need to refer to, or study about, anything aeronautical the world over should have *Aerosphere 1941*.

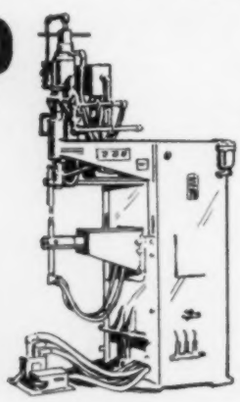
For further information write to Aircraft Publications, 370 Lexington Avenue, New York City.

STEEL CUTTER HEADS

Steel cutter heads, in operation 24 hours every day at the Fort Peck project in Montana, required repairs every three weeks. The heads mixed the dirt and water, as well as operating as a digger. Cutter heads were mounted on the end of a 40-foot ladder—the completed assembly weighing over 90 tons. Heads were removed and the blades built up. If the digging was extremely difficult, teeth were added to the blades—lengthening the life of each head by several days.

Photo courtesy Hobart Brothers Company

SPEED-UP SPOT WELDING



NEW Oakite cleaning process for aluminum helps you get MORE welds in less time!

If you are spot welding aluminum alloy structures or assemblies, you can easily SPEED-UP PRODUCTION by using a newly developed, practical Oakite process that successfully prepares metal surfaces for this operation. Interesting data mailed FREE to those requesting it on their business letterhead.

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MATERIALS & METHODS FOR EVERY CLEANING REQUIREMENT

For SAFETY SPEED ECONOMY

MANIFOLDS
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to control high pressure gases

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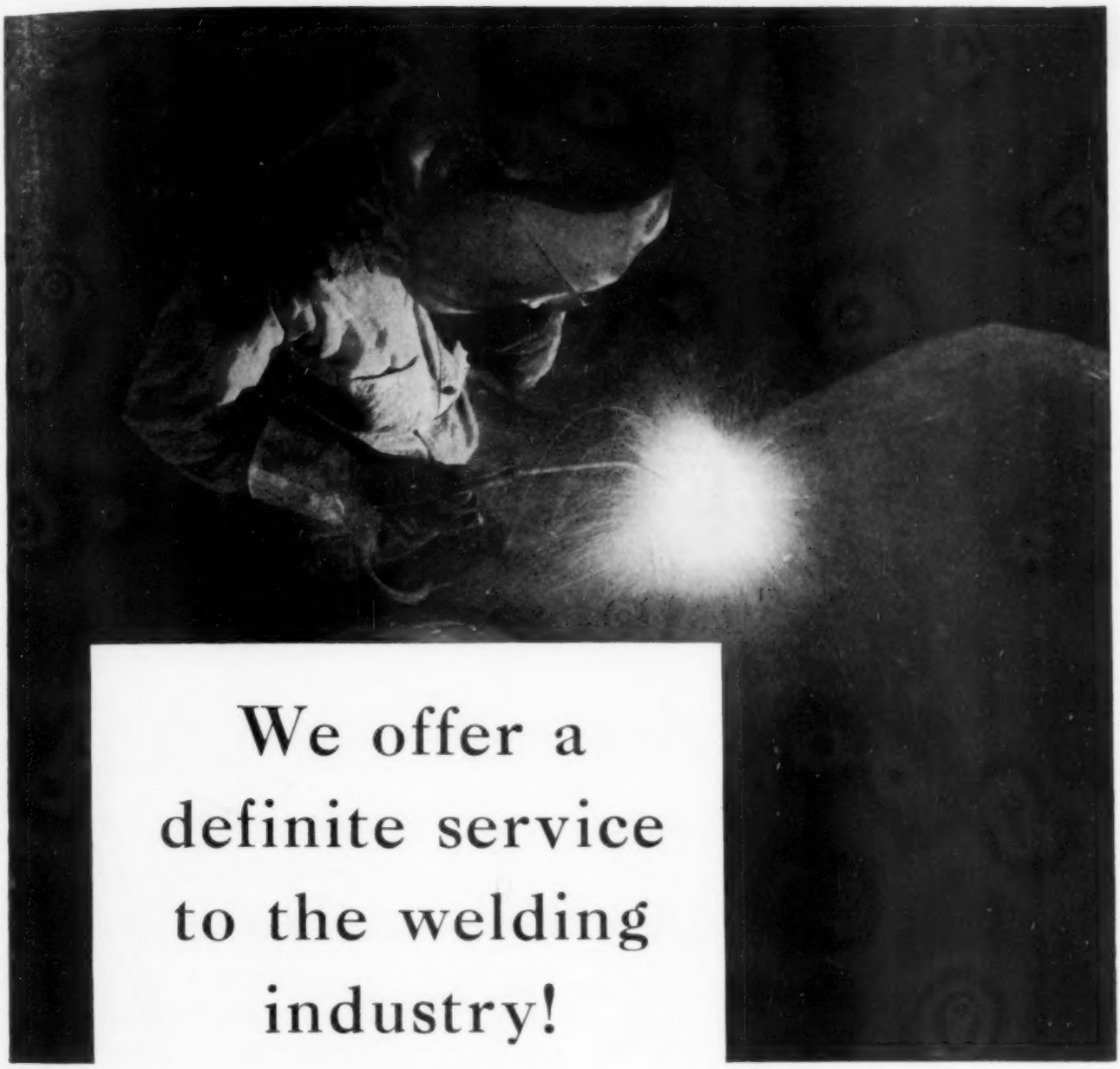
Pioneers and Manufacturers of Precision Equipment for Using and Controlling High Pressure Gases



We offer a definite service to the welding industry!

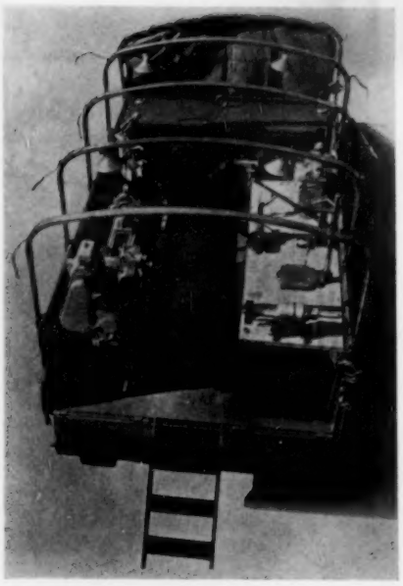
THE first thing we do when we produce a steel is to study its welding characteristics and qualifications, in order that we can recommend a definite range of uses. It is our particular interest to help you insure the success of every difficult welding job you undertake. We want to help you do away with costly, time-wasting shop experiments. For this reason, we maintain a staff of experienced welding engineers who determine just where and how the special steels we produce will best serve in all types of welding construction. This service is provided to help you take *chance* out of welding construction.

Bring your welding problems to us — let our welding engineers advise and help you — there's no obligation. Call or write today for more complete information about the service they are capable of rendering.

U·S·S ROLLED STEELS *for* WELDING

CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Export Company, New York

UNITED STATES STEEL



ARMY SHOP TRUCK

Pictured above is the Army's newest shop truck, shown by courtesy of Hobart Brothers Company, Troy, Ohio. Each unit contains a lathe, brake reliner, power generator and arc welder, valve refacer, vise drill stand and grinder. These efficient mobile shops enable Army machines to go wherever there is trouble—saving many valuable minutes of repair time.

WELDING ON THE BUILDING FRONT

Because of its timely importance, the defense front has been the object of the current welding limelight almost exclusively. This lack of attention has had no effect, however, in slowing the progress of welding on the building front. The same speedy welding methods that are applied to today's submarines and freighters are being used more and more widely on skyscrapers and factories. This photograph bears out the fact.

It shows sheet metal panels being welded in place on the Milwaukee Post Office addition. Welding on the seventh-story roof of this building required 180 feet of cable to permit "long distance" welding.

Photo courtesy Harnischfeger Corp.

STEEL "STITCHING"

Four hundred freight cars can be constructed each month with this giant spot-welding apparatus which "stitches" steel parts together with electric power. The operator here is pushing buttons of control

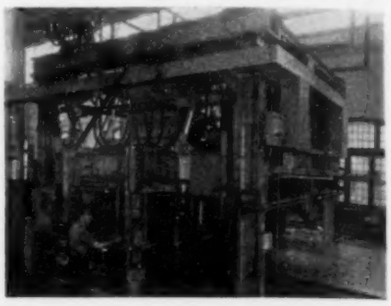


Photo courtesy Westinghouse Electric & Mfg. Co.

apparatus which sends 20,000 amperes of electric current through 75 welding electrodes in rapid succession to weld parts of the sides or top of a freight car. A side of a car may be seen entering the machine at the right. Cars constructed by spot welding are more durable and can carry three tons more freight apiece than riveted cars, according to engineers of the American Car and Foundry Company, which uses this apparatus.

The Plant Superintendent Says

"Our production curve has taken a definite upswing since we adopted Mallory Standardized Welding Tips."

Reduce the "down time" necessary for redressing and replacement to a minimum. Eliminate the "down time" caused by waiting for the completion of special orders . . . and any production curve is bound to take an upswing. And that is exactly what has been accomplished through Mallory's program of standardization of welding electrodes.

MALLORY

Resistance Welding Data Book

Your technical library is incomplete if it does not include this comprehensive reference prepared by the outstanding technicians in the field of resistance welding. Write for your copy today.

The experience gained through limitless field practice has clearly defined every requirement for greater welding electrode efficiency. Mallory Welding Electrodes are definitely better because of it. Add to this Mallory's tremendous and continuing investment in research and collaboration with welding machine manufacturers and you have the reasons behind the superiority of Mallory Welding Electrodes. Don't forego their advantages. Get all the details now.

P. R. MALLORY & CO., Inc., Indianapolis, Indiana • Cable Address — PELMALLO

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OXY-ACETYLENE WELDING AND CUTTING OF METALS

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Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them

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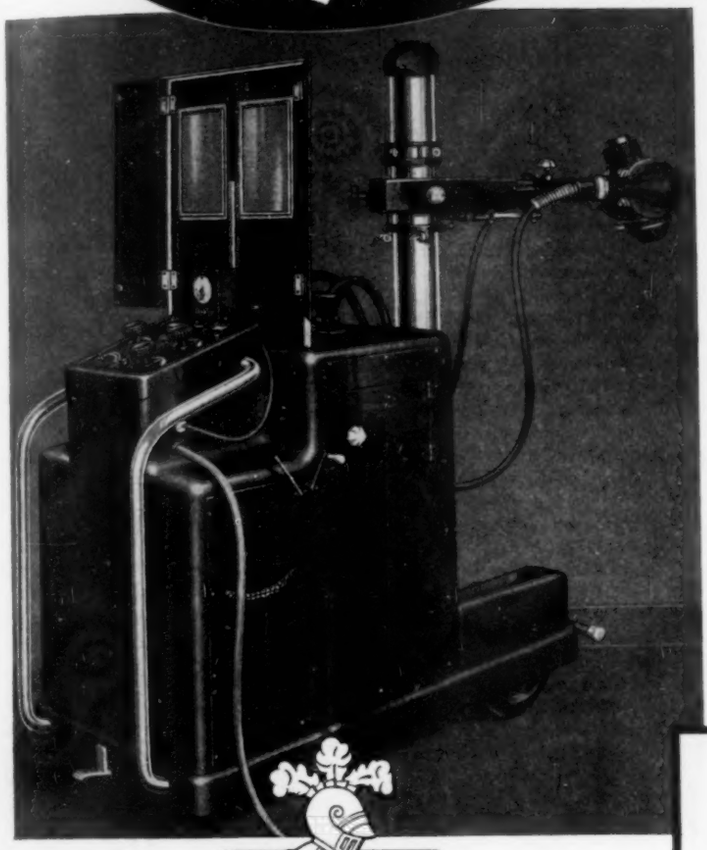
Ask for Them *Unequalled for Quality*

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4, for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; "Anti-Borax" Tinning Compound No. 11.

Send for Free Samples

ANTI-BORAX COMPOUND COMPANY
Fort Wayne, Indiana

Inspection by X-RAY



THE increasingly stringent demands put upon industry—particularly in all branches of metal working—have made it almost mandatory that X-Ray be used for inspection and examination.

Proven in the field of Medicine and in the Metallurgical Laboratory, X-Ray inspection equipment is also invaluable for industrial use. Here X-Ray provides for accurate examination by disclosing hidden defects in castings of aluminum, steel, grey iron, malleable iron or bronze and by detecting small or major flaws in all welding procedure—all without interfering with the production line.

KELEKET

INDUSTRIAL X-RAY EQUIPMENT

Industry—requisitioning the X-Ray for inspection—must decide which X-Ray equipment will be most profitable, most economical, and best adapted for each individual need. Here is where experience and reputation count. We are pioneer makers of X-Ray apparatus and have been specialists in it for 41 years. The making of X-Ray equipment is our sole business.

Because of this specialized experience we are equipped to meet the demands of industry and we have available various types and sizes applicable to the metal industry. Our engineers are at your service to advise you how a Keleket unit can solve your inspection problems—whether in the use of one of our regular, standard units or in creating and building a unit tailored to fit your specific needs. For further information, mail the coupon.

THE KELLEY-KOETT MFG. CO., COVINGTON, KENTUCKY

REPRESENTATIVES IN 64 CITIES

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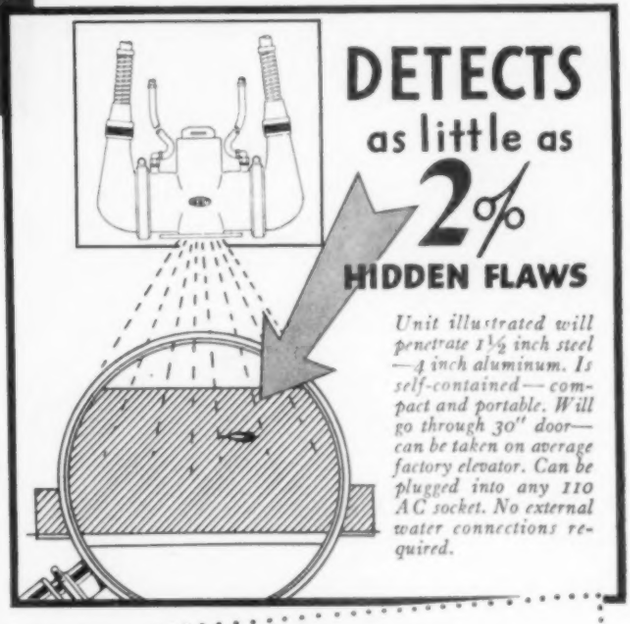
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as little as
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HALF MILLION TONS OF STEEL SAVED BY WELDING IN U. S. MARITIME 705-SHIP BUILDING PROGRAM

Saving of more than a half million tons of steel and an increase of a half million tons in cargo-carrying capacity over conventional methods of construction are being accomplished by use of welding in the 705-ship building program of the United States Maritime Commission, it was pointed out by The James F. Lincoln Arc Welding Foundation, based on a report of the Commission in Washington.

In the Commission's statement the steel saving amounts to $24,300,000 and is sufficient to construct 227 extra cargo vessels. It was stated that 2,196,000 tons are required for the current program utilizing welding, whereas under World War I conditions, when welding was not used, the same number of ships would require 2,775,000 tons.

The Commission's complete statement follows.

"Saving of more than a half million tons of steel is the contribution of modern ship designing and construction to the Maritime Commission's tremendous shipbuilding program now under way.

"That is the amount of steel that is being conserved in the construction of 705 Commission-designed ships by introduction and employment of methods not known in the first World War when this country made its last great shipbuilding effort.

"If the 705 merchant ships were built under World War conditions 2,775,000 short tons of steel would have been required. But today, under the most modern methods, they will require about 2,196,000 short tons.

"With steel selling at about $42 a short ton, the saving amounts to $24,300,000.

"Since the last war, naval architects have been on the alert for any chance to save weight in the construction of ships. Any saving in steel means less steel to buy, less material to handle, greater cargo-carrying capacity, and more economy in operation.

"The greatest single weight-saving advance has been the introduction of welding. This has so replaced riveting that, today, entire ships are being turned out without a single rivet.

Typical Examples of Ship Steel Saved by Welded Construction

Vessel	Type of Vessel	Yard Where Built	Length	Steel Saved, %
Dolomite I	Freighter	Dolomite Marine Corp., Rochester, N. Y.	213 ft. 10 in.	25
Algoma	Tugboat	Sturgeon Bay Shipbuilding & Drydock Co., Sturgeon Bay, Wisc.	45 ft.	10
Dam Yank	Towboat	Sturgeon Bay Shipbuilding & Drydock Co., Sturgeon Bay, Wisc.	165 ft.	7½
Norfolk	Freighter	Great Lakes Engineering, River Rouge, Mich.	300 ft.	16
Patty Nolan	Tugboat	Merritt-Chapman & Scott, New York, N. Y.	45 ft.	25
Studerus	Tanker	United Dry Docks Co., Brooklyn, N. Y.	64 ft. 7 in.	20
Lewis	Tugboat	Hanson Marine Ways, Galveston, Tex.	55 ft.	15
Betty H	Tugboat	Eliot Shipyard, Houston, Tex.	70 ft.	15
	Tanker	Federal Shipbuilding & Drydock Company, Kearney, N. J.	450 ft.	10

"A riveted ship is like one that is sewn together with thousands of tiny stitches with an accurately punched hole in each of the pieces joined at every stitch. The pieces joined must lap each other for the rivets to connect them.

"With a welded ship the laps and connecting pieces are largely eliminated and the hull acts as one unit rather than thousands of small parts tied together. There is a certain reduction in the friction caused by welded hulls as they glide through the water.

"Every piece of steel used in ships today is carefully examined to see if it can be eliminated or redesigned in a simpler or lighter form.

"The half million tons of steel that is saved is important in many ways. Since the ships are that much lighter it means that an extra half million tons of cargo can be carried by these 705 ships in a trip.

"Then, too, if desired, 227 extra Liberty Fleet cargo ships could be constructed out of the half million tons of steel. These ships moving together could carry 2,000,000 tons of cargo per trip."

Used widely in naval and merchant vessel construction under government supervision, welding is also rapidly replacing older structural methods in commercial programs of private owners because of its inherent advantages, according to the Lincoln Foundation.

From its files on welding, the Foundation cited typical examples showing steel savings in ship construction ranging from 7½ to 25% and averaging 15.9% over riveting.

Performing the vital service of conserving steel in the gigantic defense shipbuilding program, thus freeing the precious metal for other primary defense needs, welding has made another contribution of tremendous significance in the National Emergency. According to the Foundation, welded ships are built in 25% less time than riveted vessels. This would mean that a tanker which normally requires 6 months to construct by conventional riveting, could be built in less than 5 months.

That welding is speeding ship construction is attested by records in many yards where naval and merchant vessels are being completed months ahead of contract delivery dates.

REPAIR OF CARGO VESSELS

The main engines of damaged Axis cargo vessels are repaired without removal from the ships. In spite of the severe damage to the main engines and other vital control parts of the German and Italian cargo vessels which the United States Government took over last April, repair work is being speeded to the point where a number of these ships will again be in service by the middle of the summer. Figures 1 to 3 were taken on the Italian freighters *San Giuseppe* and *Vittorin.*

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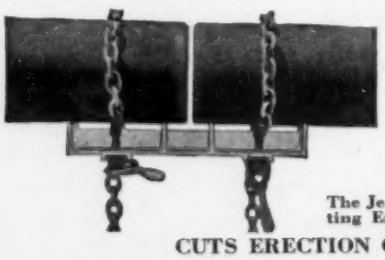

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MEETS A VITAL NEED

There has never been a greater need for the National Metal Exposition & Congress than in this year of gigantic defense preparations. This National Exhibit affords the quickest and most satisfactory way to show thousands of defense producers the newest materials, processes, and equipment for speeding defense work in the metal industry.

Many of the 35,000 men who will attend the Philadelphia Exposition have found in the present emergency that they must specify and use materials with which they are not too familiar. At the Exposition these men can see on display and in operation the products of 275 leading manufacturers in the metal industry. Five days at the Show may save five months production time for the companies these men represent.

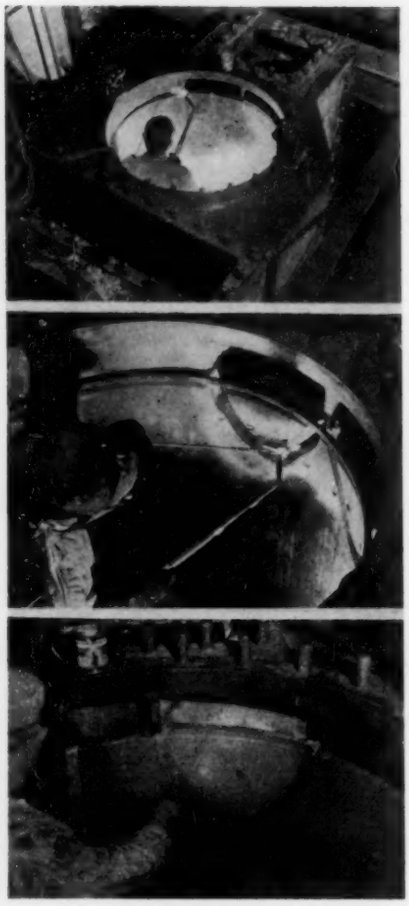
GOVERNMENT EXECUTIVES TO TALK

Sessions at the Metal Congress held in conjunction with the Exposition by four leading technical societies will be pointed toward defense production. Each morning a leading Government executive will discuss progress and requirements in Army, Navy and Aircraft production. In the afternoon, round-table sessions on various aspects of defense production in the metal industries will be conducted by armament experts. Societies cooperating in the Metal Congress are: American Welding Society, American Society for Metals, Wire Association, Iron & Steel Division and Institute of Metals Division, American Institute of Mining and Metallurgical Engineers.

EXHIBITORS PLAN BUSY WEEK

The records show that in 1941 more people than ever before are attending industrial expositions. Anticipating a crowd as large and influential as the 35,000 who attended last year's Metal Exposition, National Metal manufacturers plan an active and beneficial week during the Show.

Advance reservations are the heaviest in history; however, choice locations are still available at the regular $1.00 a square foot rate, so write, telephone or wire collect today for floor plan and full particulars. Address: W. H. Eisenman, Secretary, American Society for Metals, 7318 Euclid Avenue, Cleveland, Ohio.



Photos courtesy of The Linde Air Products Company

Figure 1 shows how bronze welding has made possible the repair of the main engines without the necessity for removing these engines from the ships.

On each ship, U-shaped sections had been broken out of the walls of the intermediate pressure cylinders just below the steam ports. After new sections were cast to fit the contour of the breaks, they were bronze welded in place as shown in Fig. 2. Starting at the bottom of the U, the operator alternated from one side to the other every 3 in., first half-filling the vee, peening the deposited metal, then completing the weld and peening. This procedure minimized contraction stresses on cooling.

Figure 3 is one of the completed welds following rough-boring. Other parts on these ships which were repaired by bronze welding include main engine valves, cylinder heads, fire pumps, air pumps, feed pumps, foundation columns and steering engines. Both the *San Giuseppe* and the *Vittorin* are under the protective custody of the Treasury Department, with repair work being supervised by the Maintenance and Repair Division of the U. S. Maritime Commission.

STREETCAR TRACKS

Indications are that a tightness in available scrap, especially of the proper grade, is becoming a serious threat to the national defense program through forcing a curtailment of steel ingot production. Steel mills cannot produce full-capacity tonnage because they must use low-grade melting steel; and they are being forced to dip deeply into their inventories of scrap, reducing them to an abnormally low point, at a time when they would normally be building up their stocks for the winter months.

In the light of this condition, a thought should be passed on to steel mills, municipalities and various types of traction companies, pointing out that thousands of tons of scrap rail can be obtained by the removal of abandoned streetcar tracks

Photos courtesy The Linde Air Products Co.

A Portable, Oxyacetylene Cutting Machine, Operating on a Special Track, Can Be Used to Cut Away Abandoned Streetcar Rail. A Cut Section of the Rail Is Shown in the Left Foreground

which are now embedded, unused, in the streets of hundreds of cities throughout the country. Furthermore, the removal of these rails can be economical and efficient through a method recently developed, in which a portable, oxyacetylene cutting machine is used.

Aside from the simplicity and high speed of cutting, which make this method so efficient, there also are economies which can be realized from adopting this method. It permits removal of the rail without breaking adjacent pavement, even when the asphalt, macadam, stone blocks or brick have been laid flush with the top of the rail. Thus, even from the standpoint of the municipality or the streetcar company, this method should be attractive. Repaving costs are kept at a minimum, and cost of removal is more than covered by the sale of the scrap rails.

In this method, the cutting machine is positioned on a special track; two or more sections of such a track can be used so that the cutting operation can be carried on continuously. The cutting blowpipe of the machine is equipped with a bevel-cutting nozzle, and a single cut is made at an angle along the groove of the rail so that the top of the rail is severed from the web in two longitudinal sections. The cut rail can then be easily removed with a pinch bar.

This Partially Cut Standard Straight Rail Indicates How a Single Cut Severs the Entire Rail Top from the Web. The Oxyacetylene Process Can Also Be Used to Cut the Rail to Charging-Box Size

ARC WELDING AT PARKER DAM

Seven arc-welding operators gang up on a penstock section for the new Parker Dam power project, Bureau of Reclamation of the U. S. Department of the Interior, at Parker Dam, California.

Employing the shielded arc process of electric welding, the huge penstock was entirely field fabricated. Automatic carbon arc welding by the "Electronic Tornado" process was used extensively. Chicago Bridge and Iron Company, Chicago, Illinois, did the fabricating and welding of the penstock.

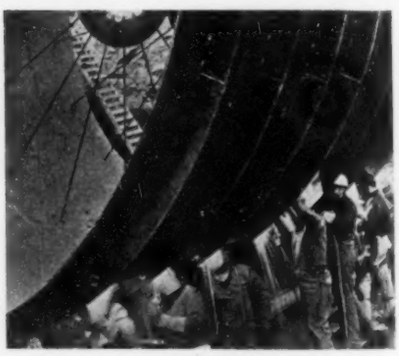


Photo courtesy The Lincoln Electric Co.

Huge cylindrical segments were placed on power-driven rollers which turned the structure into position for welding.

PASSENGER-CARGO VESSEL

America's first all-welded steel passenger-cargo vessel, *African Comet*, is shown immediately after launching on June 28th at the shipyards of the Ingalls Shipbuilding Corporation, Pascagoula, Miss.

The first of three ships of the same design, type and size, the *African Comet* this autumn will enter the service of the American South African Line which will operate the new luxury liners on a $16\frac{1}{2}$ day schedule between New York and Capetown, cutting nearly a week from current schedules.

HYDROMATICS DON'T GUESS

There is a cold certainty in the speed and accuracy with which Hydromatic multiple spot welders convert sheet metal stampings into complete assemblies. Day in, and day out, in mass production, one assembly job off a Hydromatic looks and measures up exactly like any other. That's why—where real speed counts, where accuracy demands elimination of the human element—you will find more and more Hydromatics on the job.

For "mass" production, furthermore, these machines will stack up against any other method of assembly as to cost of equipment and operation. And you don't have to wait six months or a year to get them either. Progressive's new plant and expanded design facilities are designed to keep up with any anticipated resistance welding machine requirements by industry—for defense or reconstruction.

ILLUSTRATED ABOVE

Cases for transporting loaded 25-lb. shell being assembly welded on a Progressive Hydromatic at the rate of 180 an hour. There are some 24 spot-welds per case. Assembly must be rugged and accurate to meet dimensional specifications, hold shell securely and permit stacking of the loaded cases.

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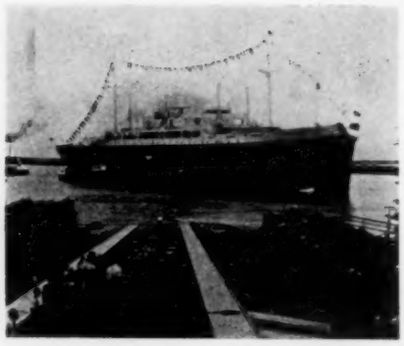


Photo courtesy General Electric Company

The *African Comet* and her sisterships, the *African Meteor* and *African Planet*, have a displacement of 17,000 tons, an over-all length of 489 feet and luxurious accommodations for 116 passengers. The vessels will average better than 18 knots. All three will utilize General Electric turbines for propulsion and turbine generators for the auxiliary power.

WELDED HEADER

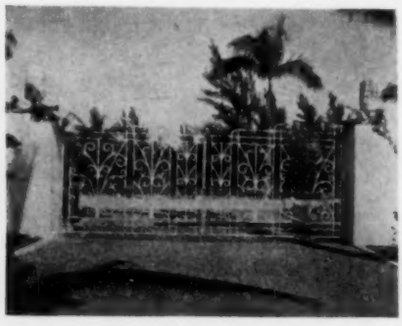
A typical and very efficient welding job on a high-pressure header is shown below. The header carries 300 lb. pressure per square inch and is constructed of pipe with a $^{5}/_{8}$-in. wall and 14 in. in diameter.

Photo courtesy Hobart Bros. Co.

The header was constructed by three pass welds using $^{5}/_{32}$-in. rods. Perfect alignment on vertical flanges was an absolute necessity since the heads were welded to sections already in place. Welding job was performed by W. A. Hudson Boiler & Welding Co. of Chicago, for Marshall Field & Co.

ORNAMENTAL IRON WORK BY ARC WELDING

Pictured below are two beautiful works of ornamental iron designed and constructed by Pullen Metal Craftmen of Miami, Fla. This type of work requires very deep penetration since the welds are ground flush before painting. Arc welding eliminates warpage and the necessity of unsightly braces. One-eighth in. electrodes were used on the lighter parts and $^{3}/_{16}$-in. electrodes on the heavier. Cost of the driveway gates is $150 while the walk gate costs $50.



Photos courtesy Hobart Brothers Co.

ALL-STEEL COAL CARS

Fifteen portable 300-ampere direct-current arc welders are being kept busy in the construction and repair of all-steel coal cars of 50-ton capacity at the Reading Company Shops, Reading, Pa. The Reading Co., is now building 1500 of these cars for its own use, assembling 32 at a time in its shop and completing 8 cars a day.

Fig. 1—Welding Being Done on One of the Cars

Photos courtesy General Electric Co.

Fig. 2—Interior of a Car at the Reading Company Shops

Arc welding is now used exclusively by the Reading Co. in the fabrication of underframe, bolster and other assemblies.

Prior to the recent application of arc welding, riveting was used in the construction of the cars. It was found, however, that reduced costs were obtainable through the use of welding, the elimination of rivet heating resulting in tremendous savings.

A repair program involving 2000 cars, on which electric welding is done in lieu of riveting, is also in progress.

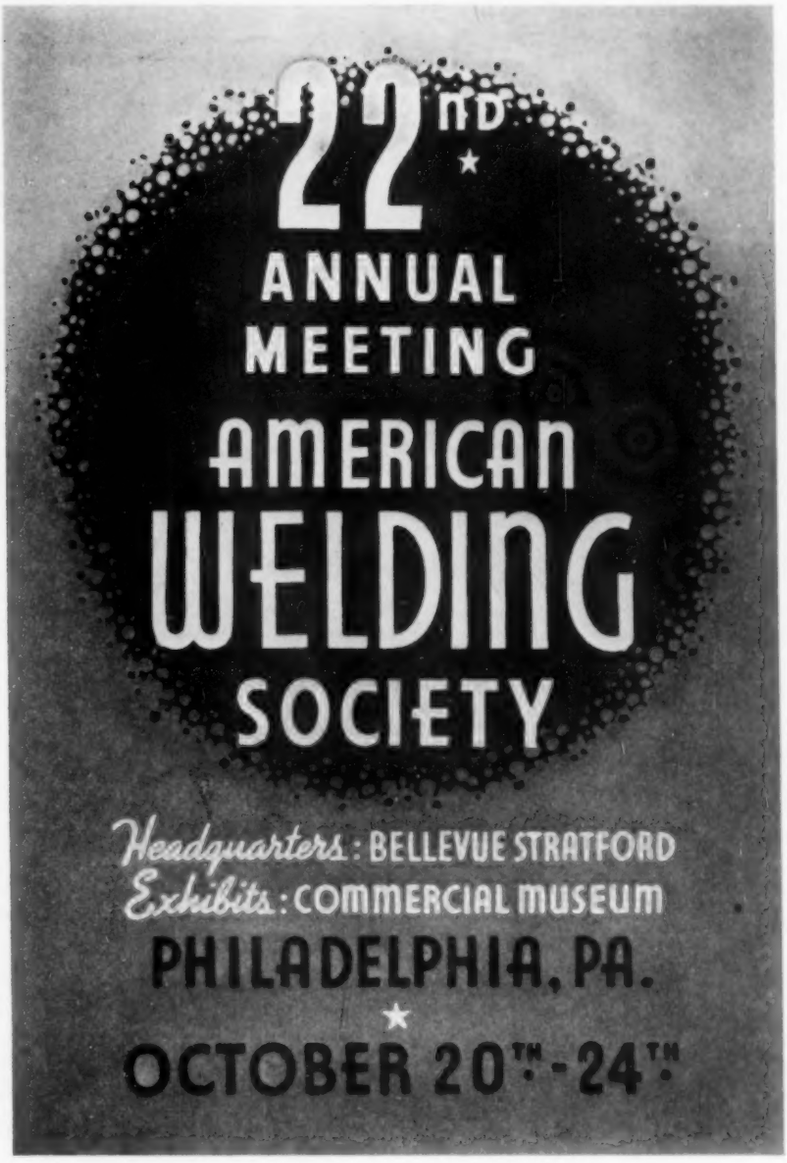
PYROMETRY

By William P. Wood, A.N., M.S., and James M. Cork, Ph.D. Published by McGraw-Hill Book Company, Inc., 263 pages, price $3.00.

Industrial developments during the last quarter century have made the accurate measurement of temperature one of the most important phases of the processes involving the production or application of heat. In many plants the entire time of one or more skilled technicians is occupied in maintaining the pyrometric system. This condition has been reflected in colleges and universities by the establishment of separate courses in temperature measurements. Such courses are usually offered by the Engineering or Physics departments.

SILVER BRAZING

The new Bulletin No. 12 of Handy & Harman, 82 Fulton Street, New York, tells a complete detailed story about the low-temperature silver brazing alloys Sil-Fos and Easy-Flo. The bulletin does more than just give the advantages these alloys provide in making reliable, low cost joints between metals. It also gives data that should be very helpful in putting these alloys to use in a manufacturer's plant. Copies may be obtained on request.



Sessions devoted to NATIONAL DEFENSE, SHIPBUILDING, AIRCRAFT and AUTOMOTIVE INDUSTRIES and many other interesting and timely subjects.

★

In the light of the defense program and the many new developments and applications of welding your attendance this year is more important than ever. You owe it to yourself to be present.

AMERICAN WELDING SOCIETY

33 West 39th Street, New York, N. Y.

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

A NEW TIME SAVER FOR ARC WELDING

Engineers, supervisors, purchasing agents, operators and all others who use or supervise the use of arc-welding electrodes will want a copy of the new *General Electric Arc Welderule* because of the time it saves in estimating electrode requirements. Operating in a manner similar to a slide rule, the Arc Welderule reads directly the length of arc-welded joints obtainable per 100 lb. of electrode, also the pounds of weld metal deposited per 100 lb. of electrode. The information covers 11 different commonly used sizes and types of joints; also 22 different sizes and types of popular electrodes in both the 14- and 18-inch lengths.

Although general data of a similar nature has been published in bulletin form, the new Arc Welderule enables more accurate estimates to be made because it applies to specific types and sizes of electrodes. Being of vest-pocket size, it is also handier, easier and more convenient to use in getting the answer quickly.

An additional feature of the Arc Welderule is a *selector chart* which shows the various filler metal classifications as specified by the AMERICAN WELDING SOCIETY and the types of electrodes which meet these classifications. This new Arc Welderule may be obtained from any local G-E Arc Welding Distributor, G-E Sales Office, or from General Electric Company, Schenectady, N. Y.

WELDING POSITIONER

This machine is designed to expedite the welding of heavy machine parts or structural material by permitting downhand welding for all welds. This is made possible by revolving the piece to be welded through an area of 90° from the horizontal and 360° about the center line of the piece to be welded. This revolving permits the piece to be always kept at the best angle to produce a good weld in the shortest possible time.

Photo courtesy Machinery & Welder Corp.

The movement of the table is controlled by push buttons within easy reach of the operator. The table moves in either direction and only operates while the push button is held down. To prevent the tilting of the entire unit beyond its predetermined limit, a limit switch is placed at each end of the travel. A solenoid brake holds the machine in position when the current is off.

The table size is 13 ft. 11 in. in diameter and permits the attaching of large sections to it.

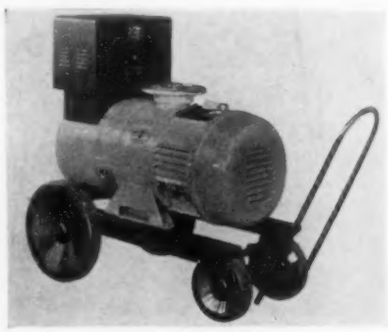
This unit was manufactured by the Mississippi Valley Structural Steel Company, Melrose Park, Illinois.

CRATER ELIMINATOR

Crater formation in metallic arc welding is known to be caused by abrupt breaking of the welding arc, which does not give the molten metal at the end of the deposit an opportunity to become free of gases and slag. The two outstanding characteristics of the deposited metal in the crater area are porosity and a distinct depression in the contour of the deposit. Wilson Welder & Metals Company, 60 East 42nd Street, New York City, announces the "Stroco" Electric Arc Crater Eliminator for use where the presence of the typical crater at the end of a weld deposit is objectionable.

The "Stroco" Crater Eliminator is an auxiliary device which is mounted on the body of the arc-welding generator. It is connected in series with the excitation field of the generator and controlled by a switch which enables the operator to cut it in and out of the excitation field circuit at will. When introduced into the circuit it functions as a variable resistance of large enough capacity to build up the resistance in the excitation field and thus lower the excitation field, thereby making it possible to reduce the current density gradually without disturbing the current setting of the welding generator. It is thus possible to accomplish a tapering off or a fading of the current instead of an abrupt change. The weld deposit made under these conditions is free from porosity at the end and has a smooth, even contour instead of the typical depression.

Control of the "Stroco" Eliminator is by means of a three-position button switch located on the electrode holder. During the usual progress of the weld, the switch is in the neutral position and the device is entirely inoperative. When the operator is about to break his arc either because he is approaching the end of one electrode or because he is approaching the end of a weld, he presses the button backward into the "ON" position of the switch housing. This brings the "Stroco" Crater Eliminator into play and causes the arc to fade out gradually until the arc voltage becomes so low that it can no longer deposit any metal. In any case where the sections of the parts being joined become smaller so that it is desirable to reduce the current density for a limited period, the button can be retracted to make a slight reduction in the welding current and then advanced into the "OFF" position so that the remainder of the weld can be completed with reduced current; or, if he wants to return to the original current, a release of the pressure on the button will let it swing into the neutral position, which in turn will cause an increase of the welding current to its original value.



"Stroco" Electric Arc Crater Eliminator Attached to Wilson "Hornet" Arc Welding Generator

COMBINATION VALVES

The new RegO 2580 and 2581 LP Gas Valves, manufactured by The Bastian-Blessing Company, 242 East Ontario Street, Chicago, Ill., are designed especially for use with permanently installed ICC cylinders and A. S. M. E. or A. P. I.-A. S. M. E. above-ground containers. They are suitable for use with either flash or batch vaporization.

This series of RegO valves embodies in one simple assembly all of the following safety and utility features: shut-off valve for outlet connection; excess flow check valve for outlet connection; automatic quick filler valve and back pressure check valve; supplementary back pressure check valve; safety relief valve; fuse plug; fixed liquid level gage and vent valve; variable

positioning container inlet connection; and liquid eduction outlet tube. Only one connection is required in the container.

The RegO 2581 Valves are also equipped with elbow outlet adapters and loose rain caps on the safety relief valve and at the fuse plug discharge.

"ANTI-SPATTER"

For jobs where a weld is to be neat and free from spatter, Thompson's "Spatter-Off" has been developed to allow its easy removal. Spatter may fly and settle thickly about the weld, yet when "Spatter-Off" has first been applied, all the spatter may be readily brushed off. "Spatter-Off" is furnished for jobs that are to be pickled, and also for where there is no pickling and the work is to be painted over. A new descriptive folder on "Spatter-Off" has been issued, and may be had by addressing the makers, Thompson & Company, P. O. Box 6757, Pittsburgh, Pa.

INDUSTRIAL TYPE WELDERS—POWER FACTOR CORRECTED

Four models for production work on manual or automatic welding are available in a new line of transformer type welders with built-in power factor correction. They are designed to reduce current consumption, which will help out the power supply under the Defense Program due to the fact they will only use two-thirds as much current as standard types of arc welders. Because of the decreased kva., smaller wire, switches, cable and fuses can be used, resulting in considerable saving in installation costs and also reducing demand charges by approximately one-third.

These units answer a twofold purpose for when not in use as arc welders, they can be used to correct the power factor of present installations, which will also result in less heating of the present power circuit.

Built to conform to N. E. M. A. standards, these welders employ Class B insulation, i.e., asbestos and fiberglass, and feature two open circuit voltages—80 and 100. Thus, the operator is enabled to choose the correct voltage for the work at hand, which affords both maximum arc flexibility and lowest power costs. The higher voltage is an advantage when welding with alloy electrodes, giving a smoother more stable arc, and the lower voltage is sufficient on general work.

The amperages, shown by the indicator on the front of the cabinet, may be adjusted without breaking the arc simply by turning the ball crank handle which gives an infinite number of heat stages, making the units extremely simple to operate. They are built in 300, 400, 500 and 600 ampere sizes by Miller Electric Mfg. Co., Inc., Appleton, Wis.

ELECTRIC SILVER SOLDER BRAZING UNIT

A new electric brazer for brazing and soldering with silver solder is announced by the Ideal Commutator Dresser Co., 1938 Park Avenue, Sycamore, Illinois.

This brazer operates on the same principle as the popular Ideal "Thermo-Grip" soft soldering tools. It consists of a power unit or transformer and a pair of electric heating pliers. Holding the part to be brazed in the pliers closes the secondary circuit causing the part to quickly heat to brazing temperature. Heat is accurately controlled by On-Off foot switch.

The Ideal brazer is compact, portable, easy to use and always ready in shop or field. When in use the cover turns back making a convenient shelf for flux, silver solder, etc. Compartments are provided for heating pliers, foot switch, silver solder and flux. When not in use all parts can be enclosed and out of the way in the streamlined cabinet which is readily portable on easy rolling casters. Over-all size is only 14 x 12 x 25 in. Weight, 100 lb. (60 cycle unit), 150 lb. (25 cycles).

ALL-WELDED DIPPER

A number of significant features have been incorporated in the new P&H $1^1/_2$ cu. yd. all-welded dipper announced by the Harnischfeger Corporation of Milwaukee for their Model 655-A Hydraulic Excavator.

New All-Welded Dipper for P & H 655-A Excavator

Besides stability gained by the welded construction, there are the advantages of a renewable manganese lip, renewable dipper teeth and improvements in the latching mechanism. By providing a heavy shell, simplicity of reinforcements and an exceedingly sturdy padlock frame with large sheave, a maximum in over-all strength and rigidity has been secured. Also important is the absence of corner welds—a feature achieved by forming the dipper back of the parent metal instead of the inserted plate type back.

Employment Service Bulletin

SERVICES AVAILABLE

A-415. Welding Inspector. Three and a half years' experience in high-pressure welding. Passed regular and armor-plate Navy tests. Will graduate in September from Newark College of Engineering where he is taking National Defense Course, Materials Testing and Inspection.

SECTION ACTIVITIES

KANSAS CITY

The following officers for the fiscal year were elected by the Kansas City Section at a dinner meeting held on May 6th.

Chairman, L. R. St. John, Kansas Hi-Way Dept.; *Vice-Chairman*, J. R. Streeter, Black, Sivalls & Bryson; *Secretary*, Carl Peterson, Welding Equipment Supply Co.; *Treasurer*, Vic McDonald, Fairfax Eng. Corp.

Mr. C. W. Metzer of Haynes Stellite Co. showed three reels of moving pictures on Hard Facing, which were followed by discussion.

NORTHERN NEW JERSEY

The second annual outing of the Northern New Jersey Section was held at Angele's Grove, Allen Avenue off Burnett Ave., Union, N. J., on September 6, 1941, starting at 11 A.M. Luncheon, refreshments and sport events, including soft ball and soccer, were included in the admission price of $2.00.

PITTSBURGH

At a meeting of the Officers and Executive Committee of the Pittsburgh Section held Thursday evening, July 24th, in the Wm. Penn Hotel, the following committee members were selected and unanimously approved to serve during the 1941–42 season:

Membership and Reception: A. J. Deacon, *Chairman*, R. C. Waldie, H. T. Thompson, R. B. Lincoln, R. W. Emerson.

Program and Entertainment: G. F. Wolfe, *Chairman*, C. H. Jennings, F. H. Dill.

It was voted to continue meeting in the beautiful Mellon Institute of Industrial Research Building in Oakland, and the secretary was instructed to proceed with the reservation of the Auditorium for the following nights: Wednesday—October 15, November 19, January 21, 1942, February 18 and March 18. The date and place for the Annual Tri-State Welding Conference is to be selected later. No meeting is scheduled for December.

List of New Members

July 1 to July 31, 1941

BIRMINGHAM

Durham, J. U. (C), American Bureau of Shipping, 929–31 Stahlman Bldg., Nashville, Tenn.

CANAL ZONE

Brown, Lionel W. (D), P. O. Box 831, Diablo Hgts., C. Z.

CHATTANOOGA

Copenhaver, Clyde (C), Combustion Eng. Co., 1032 Main St., Chattanooga, Tenn.

CHICAGO

Schiebel, Roy O., Jr. (C), Magnaflux Corp., 5908 Northwest Highway, Chicago, Ill.
Svanoe, William H. T. (B), Utilities Engrg. Inst., 1314 Belden Ave., Chicago, Ill.

CINCINNATI

Hock, Alvin, Jr. (D), Brighton Works, 2159 Kindel Ave., Cincinnati, Ohio.
Kisner, Earl (D), E. W. Buschman Co., 418 New St., Cincinnati, Ohio.

CLEVELAND

Applegate, R. R. (C), Champion Rivet Co., E. 108th & Harvard Ave., Cleveland, Ohio.
Champion, T. P. (B), Champion Rivet Co., E. 108th & Harvard Ave., Cleveland, Ohio.
Collis, Walter (C), Champion Rivet Co., E. 108th & Harvard Ave., Cleveland, Ohio.
Gaines, W. S. (B), Porcelain Steels Co., Cleveland, Ohio.
Louis, C. (C), Champion Rivet Co., E. 108th & Harvard Ave., Cleveland, Ohio.
Silliman, W. A. (B), Cleveland Tractor Co., E. 193 St. & Euclid Ave., Cleveland, Ohio.
Washington, F. M. (C), Champion Rivet Co., E. 108th & Harvard Ave., Cleveland, Ohio.

DETROIT

Hess, Edwin J. (C), 3862 Iroquois Ave., Detroit, Mich.
Kolkloesch, Harold (C), 2620 W. Michigan Ave., Ypsilanti, Mich.

GEORGIA

Dillon, John F., Jr. (D), Le Tourneau Co. of Ga., Toccoa, Ga.

LOS ANGELES

Miller, Clay W. (C), Signal Hill School of Welding, 1207 E. Hill St., Long Beach, Calif.
Mitchell, Sam (C), 1634 Federal Ave., Los Angeles, Calif.

NEW YORK

Christensen, Hans A. (B), 3727—85th St., Jackson Hgts., N. Y.
Davis, Norman (C), The Linde Air Products Co., 30 E. 42nd St., New York, N. Y.
Weishoff, Samuel (B), 2715 Grand Concourse, New York, N. Y.

NORTHERN NEW JERSEY

Boylan, Joseph J. (D), 298 Bergen Ave., Jersey City, N. J.
Christensen, Magnus (B), Babcock & Wilcox Co., Bayonne, N. J.
Damick, Joseph (D), 632 Roosevelt Ave., Carteret, N. J.
Gallagher, Patrick (D), 38 Kelly Pkwy., Bayonne, N. J.
Hagey, Eugene (D), 185 Ogden St., Newark, N. J.
Jasmine, Joseph J. (D), 209 Union St., Lodi, N. J.
Koch, Harry (D), 910—16th St., Union City, N. J.
Sage, Albert M. (C), Steiner-Ives Co., 14 Avenue L, Newark, N. J.
Van Dyk, Wilmer (D), 20 Clara St., R. R. 3, Paterson, N. J.

NORTHWEST

Behringer, Cecil R. (D), 5420 Aldrich Ave., So., Minneapolis, Minn.

OKLAHOMA CITY

Bainum, Cliff (D), Oklahoma A. & M. College, Stillwater, Okla.

PHILADELPHIA

Holder, Edward H. (D), 420 Timber Lake Rd., Upper Darby, Pa.
Irrgang, Harry J., Jr. (B), W. K. Mitchell & Co., 2940 Ellsworth St., Philadelphia, Pa.
Metzler, D. E. (B), Philadelphia Ordnance Dist., Berwick Sub-Office, care of American Car & Fdy. Co., Berwick, Pa.
Sack, Raymond G. (D), Tuckahoe, N. J.
Smith, Benjamin J. (D), Stonehouse Lane, Philadelphia, Pa.

PITTSBURGH

Kmet, John J. (C), 230 S. Central Ave., Canonsburg, Pa.

SAN FRANCISCO

Cavallero, J. T. (B), Oliver United Filters, Inc., 2900 Glascock St., Oakland, Calif.
Croft, E. L. (D), Oliver United Filters, Inc., 2900 Glascock St., Oakland, Calif.
Hieronymus, S. J. (B), 2838 Lyon St., San Francisco, Calif.
Schoning, Wm. D. (B), American Bureau of Shipping, 1026 Matson Bldg., San Francisco, Calif.

SOUTH TEXAS

Wade, Clyde E. (D), 6653 Avenue O., Houston, Texas.

WASHINGTON, D. C.

Argabright, James A. (D), 2315 Chestnut Ave., Newport News, Va.

YOUNGSTOWN

Falls, Theodore F. (C), 1185 High St., N.E., Warren, Ohio.

NOT IN SECTIONS

Beutel, Herbert W. (C), Mosher Steel Co., Box 2248, Dallas, Texas.
Hamilton, Harold (D), R. F. D. 6, Berneway Dr., Ft. Wayne, Ind.
Wright, Louis (D), Air Reduction Sales Co., 1256 Logan St., Louisville, Ky.